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Original Article

Growth and mortality parameters of Caspian kutum, *Rutilus kutum*, in southern Caspian Sea

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Abstract: The Caspian Kutum, *Rutilus frisii*, is one of the endemic and most important commercial cyprinid species in the southern Caspian Sea. A detailed study on growth and mortality parameters of this species was conducted based on 700 samples collected from commercial catches of beach seining in Guilan and Mazanderan provinces during fishing season 2017-2018. Females were dominated in both studied populations. Size frequency distributions showed significant variation among same sexes and between different sexes. The different WLRs were observed, positive allometric in Mazanderan, and negative allometric in Guilan. There were significant differences in growth parameters between sexes, females were of much greater asymptotic length than males, while the male fish had a higher growth rate and attained a smaller theoretical L_∞ size than females. The theoretical maximum length (L_∞) was larger than the maximum one recorded during sampling. Based on the Bhattacharya method, the Caspian kutum from Guilan fishing grounds was more diverse, and included nine cohorts, while the population from Mazanderan Province showed only six cohorts. The linearized catch curve based on age composition data showed that total mortality rates (Z) are 1.32 year^{-1} and 0.63 year^{-1} for males and females of Guilan, respectively, that of males in Mazanderan is 1.04 year^{-1} and of females 0.86 year^{-1}. The natural mortality rates (M) were 0.48 year^{-1} for males and 0.26 year^{-1} females in Guilan, and was found to be as 0.26 year^{-1} and 0.45 year^{-1} for males and females of Caspian kutum caught in Mazanderan. The exploitation ratio (E) was found to be higher than 0.5 for both sexes from Guilan, and to be lower than the expected optimum level of exploitation in Caspian kutum males and females caught in Mazanderan.

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Introduction

The ichthyofauna of the southern Caspian Sea basin includes 119 species belong to 63 genera (Esmaeili et al., 2014, 2018). Caspian kutum, *Rutilus kutum*, is endemic to this basin occurring mainly in the southern coast of the Caspian Sea with a distribution extending from the Terek River in the north to the Gorgan Bay in the southeastern region. This species is among of the most important commercial species for fisheries and stock enhancement programs in the Iranian Caspian coast (Kiabi et al., 1999; Farhang and Eagderi, 2019). Despite intensive investigations on Caspian kutum in the context of aquaculture and ecotoxicology, few publications are available on its growth parameters (Abdolmaleki et al., 2007; Hoseini et al., 2010; Aghili and Mohamadi, 2011; Fazli et al., 2013). However, no paper has so far considered the variation in growth of different populations of this species on a relatively broad regional scale.

Fish growth is an indeterminate plastic process that can change considerably among populations of a species in its distribution areas. Furthermore, growth parameters are not only required input to several stock assessment methods, but also allow tests of life-history hypothesis (Stergiou, 2000). Therefore, verification of local values and growth variability within species (considered as inter-population variations) has great importance in fisheries ecology and fish population dynamics. Hence, this study aimed to investigate in greater detail growth aspects of

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Caspian kutum from two main fishery areas, to increase our knowledge on the variability of its growth parameters. The results could be used for better and effective management practices of exploiting the species stock in this basin.

Materials and Methods

The samples were collected from commercial catches in fishing grounds of Guilan and Mazanderan provinces during 2017-2018 fishing season i.e. fall and winter. However, the size range did not include individuals smaller than the size at first capture because they were not selected by the commercial fishing gears. The fishing operations in these areas are conducted using huge beach seine with mesh sizes of 26–32 mm. Then, the collected specimens were transported to the laboratory, where their fork length (FL; ±0.1 mm) and total weight (W; ±0.1 g) were recorded. All specimens were dissected to determine their sex by direct observation of the gonads. In addition, 5-10 scales of each individual were removed from the area just above the lateral line and mounted between two glass slides for age estimation. Two readers interpreted the growth marks on scales without prior knowledge of length, weight or sex of the fish, its date of capture or the previous reading to avoid reading bias. Only coincident readings were accepted.

To describe size structures of the populations studied, histograms of size-frequency distributions of the Caspian kutums were made, using 4 cm FL intervals. Two-sample Kolmogorov–Smirnov (K–S) tests (α=0.05) were used to compare size frequency distributions between sexes (Sokal and Rohlf, 1981). Estimation of the Weight and length relationship was made by adjustment of an exponential curve to the data (Ricker, 1975): $W = aL^b$, where W is the total weight (g), L the fork length (cm), a the intercept (initial growth coefficient or condition factor) and b the slope (allometric exponent). The relationship coefficients were calculated using non-linear least squares estimation. Student's t-test was applied to determine the significance of differences between the isometric growth and the estimated b-value of the equation. Additionally, an analysis of covariance was used to compare FL–W relationships between sexes (Keivany et al., 2016).

Estimates of theoretical growth in length were obtained by fitting the von Bertalanffy growth function (VGBF) to the mean length at age data separately for males and females by non-linear regression: $L_t = L_\infty[1-e^{-k(t-t0)}]$ using the method of Gulland-Holt (Everhart and Youngs, 1975), where L_t is the length at age t, L_∞ is the asymptotic length, k is the growth coefficient, and t_0 is the hypothetical time when the fish total length is zero. The overall growth performance index ($Ø'$) was calculated based on the growth parameter estimates by the equation of Munro and Pauly (1983): $Ø' = \log_{10}k + 2 \log_{10} L_\infty$. The index was used to compare growth parameters obtained in this study with those reported by other authors. In addition, the weight-based of VBGF calculated as $W_t=W_\infty[1-e^{-k(t-t0)}]^b$, where W_t is the weight of the fish in g at age t, W_∞ is the asymptotic weight of the fish in g and b is the constant in the length–weight relationship (Ricker, 1975; Sparre and Venema, 1992).

Monthly length-frequency data was analysed using the package FISAT model progression analysis, and Bhattacharya's (1967) method subroutine (Sparre et al., 1989; Gayanilo et al., 1994) for to identify the modes in the polymodal length-frequency distributions of Caspian kutum cohorts. The total mortality rate (Z) for each sex of population was estimated using Powell Weatherall plot, where the regression equation has the form $ln(N) = a + bt'$, where N is the number of fish in cohorts by means of successive growth curves, t' is the relative age of the fish in that cohort, and b with the sign changed provides an estimate of Z (Powell, 1979; Wetherall et al., 1987). To obtain an independent estimate of natural mortality rate (M), the Pauly's empirical equation (1980) $log(M) = -0.0066-0.279\ log(L\infty) + 0.6543\ log(K) + 0.4634\ log(T)$ was employed. Here, T is mean annual habitat temperature in southern Caspian Sea and L_∞ is expressed in cm.

Results

A total of 700 Caspian kutum were collected from

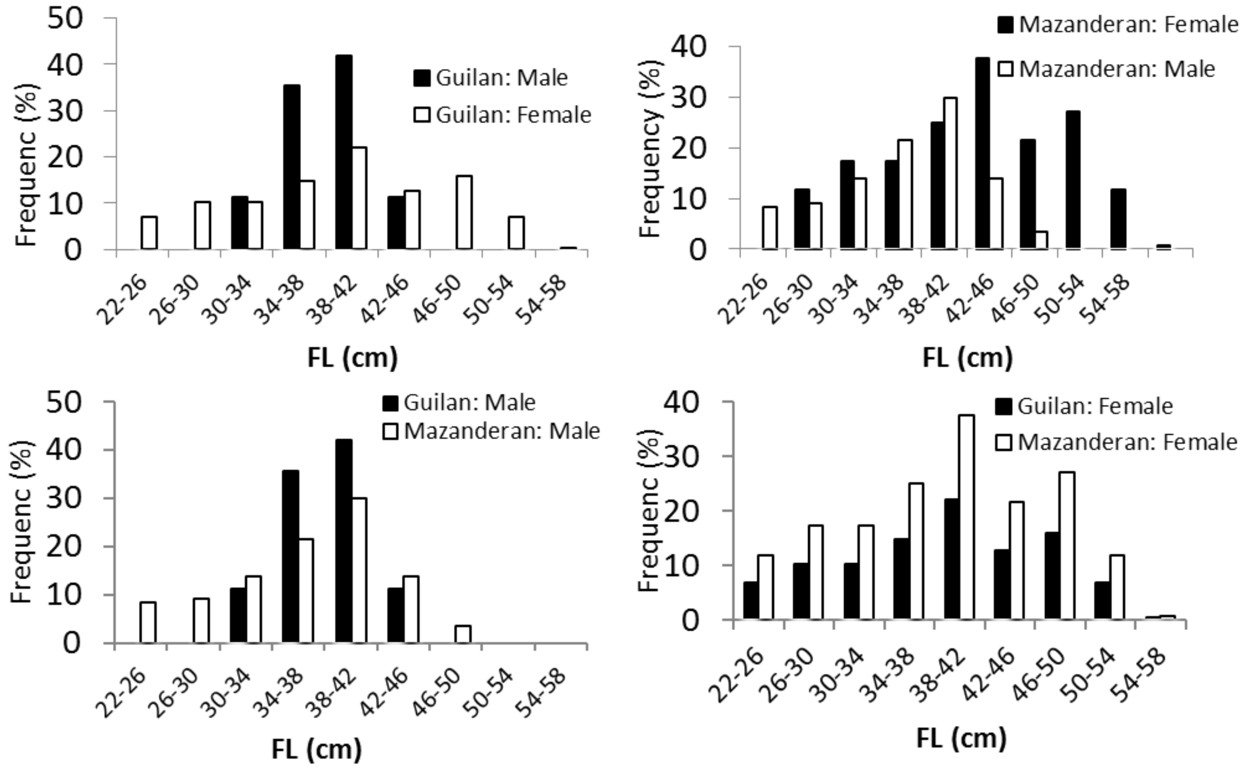

Figure 1. Relative proportion (%) of Caspian kutum males and females from southern Caspian Sea (2017-2018).

Table 1. Growth parameters of the Caspian kutum from southern Caspian Sea (2017-2018).

Location	Sex	Year	$W_{\infty(gr)}$	$L_{\infty(FL,cm)}$	$k(year^{-1})$	$t_{0(year)}$	Z	M
Guilan	Male	2017-2018	2053.41	60.74	0.20	-0.68	1.32	0.48
Guilan	Female	2017-2018	4356.91	69.12	0.14	-0.99	0.63	0.26
Mazanderan	Male	2017-2018	1610.10	52.77	0.36	-0.39	1.04	0.26
Mazanderan	Female	2017-2018	2396.10	69.12	0.14	-0.99	0.86	0.45

commercial catches in the Guilan (n=310) and Mazanderan (n=390) provinces. The number of females sampled was statistically more than the number of males sampled (χ^2=46.27, P<0.05). In both sampling areas, the sex ratio was almost the same (1:1.7) in favour of females (Guilan: χ^2=19.6, Mazanderan: χ^2=26.7, P<0.05). Size frequency distributions showed significant variation among same sexes and between different sexes (K–S test, P<0.05) (Fig. 1).

The length–weight relationships (WLRs) of males and females in both populations are given in Figure 2. The WLRs for females and males were significantly different (P<0.05). Therefore, the female and male data cannot be pooled. Different types of growth were observed: positive allometric in males and females from Mazanderan, and negative allometric in both sexes of Guilan (t-test, P<0.05).

Table 1 summarizes The von Bertalanffy growth parameters and mortality rates estimated from our data set. There were significant differences in growth parameters between sexes, females were of much greater asymptotic length than males, while the male fish had a higher growth rate and attained a smaller theoretical L_∞ size than females. The theoretical maximum length (L_∞) was larger than the maximum one recorded during sampling and no samples reached or were longer than the theoretical value of calculated for each sex. The plots of von Bertalanffy growth functions for males and females fitted to the observed length and weight-at-age data of each sex and year separately show that the growth patterns of females

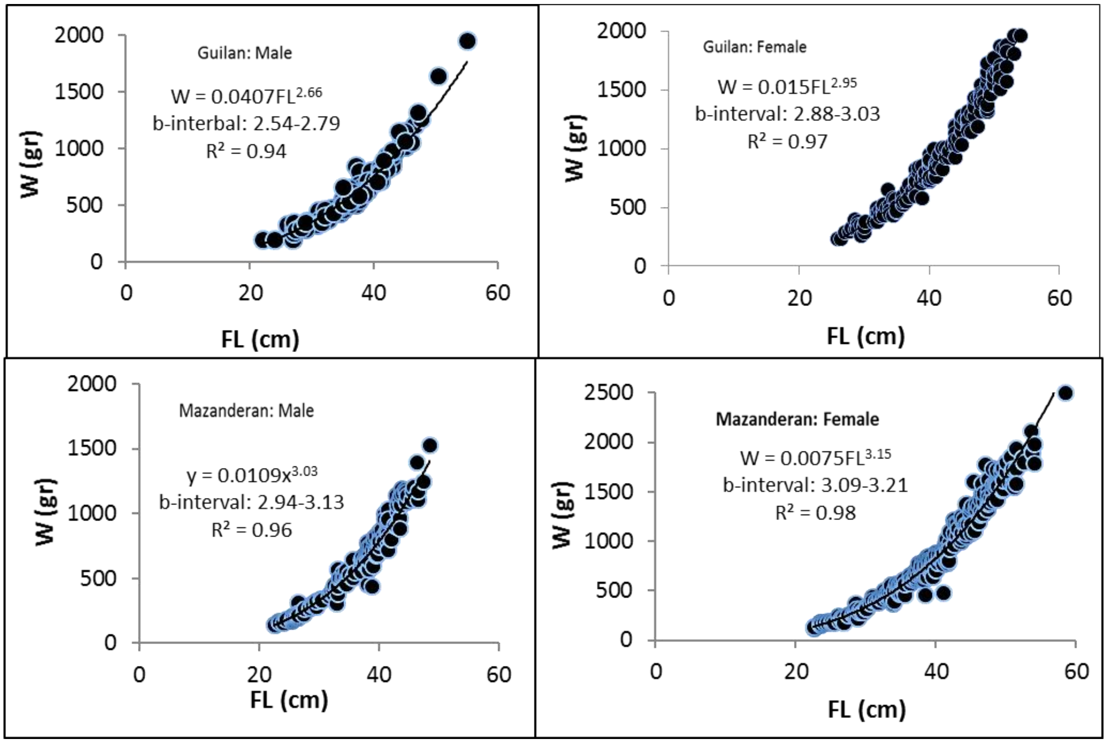

Figure 2. Fork length–weight relationship for combined sexes, as well as male and female Caspian kutum, southern Caspian Sea (2017-2018).

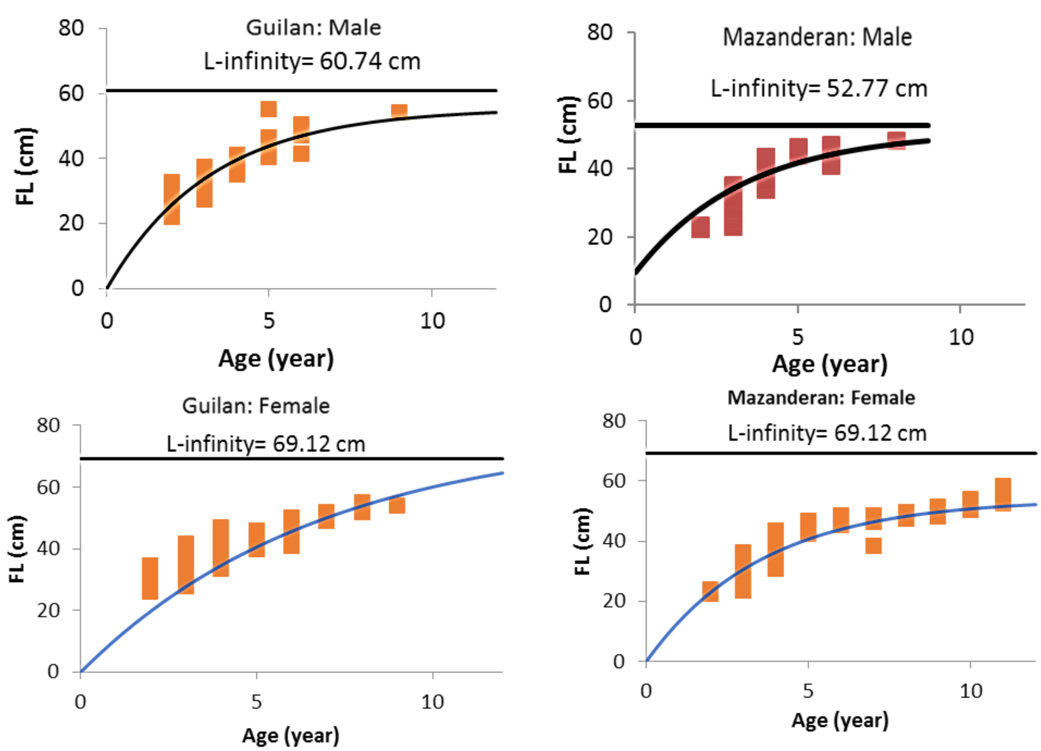

Figure 3. Length-age based von Bertalanffy growth model for the Caspian kutum sampled in southern Caspian Sea (2017-2018).

and males are similar in younger ages, thereafter; females grew to be larger than males (Figs. 3, 4).

The Bhattacharya method showed different cohorts in commercial catch of Caspian kutum in the southern area (Fig. 5). The Caspian kutum from Guilan fishing grounds was more diverse, and included nine cohorts, while the population from Mazanderan Province showed only six cohorts. The linearized catch curve

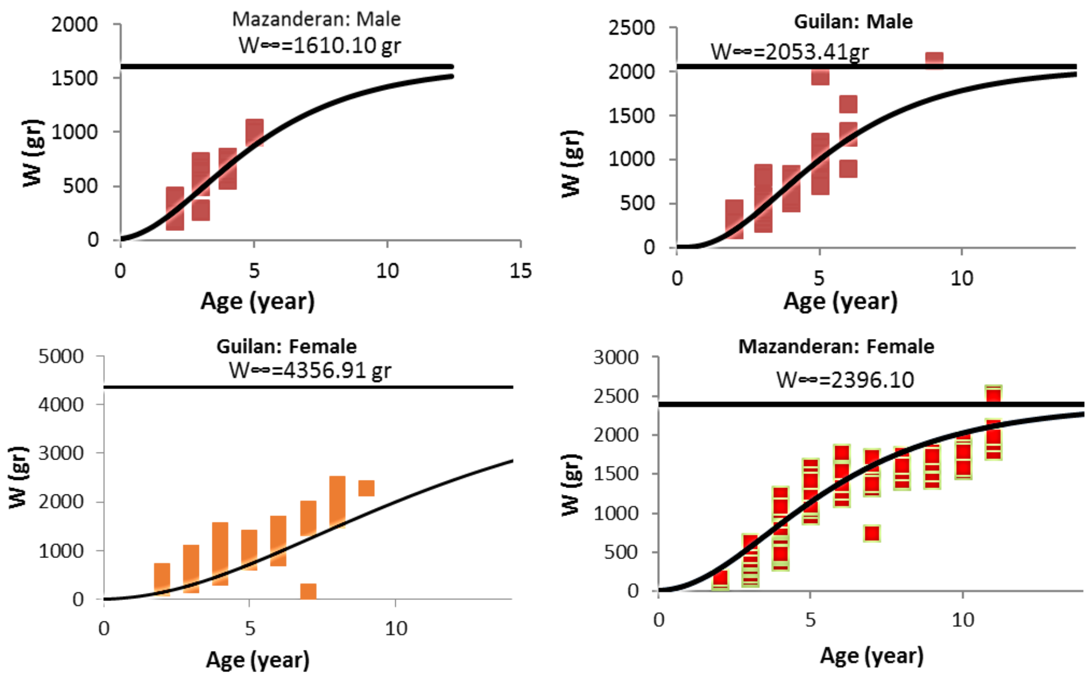

Figure 4. Weight-age based von Bertalanffy growth model for the Caspian kutum sampled in southern Caspian Sea (2017-2018).

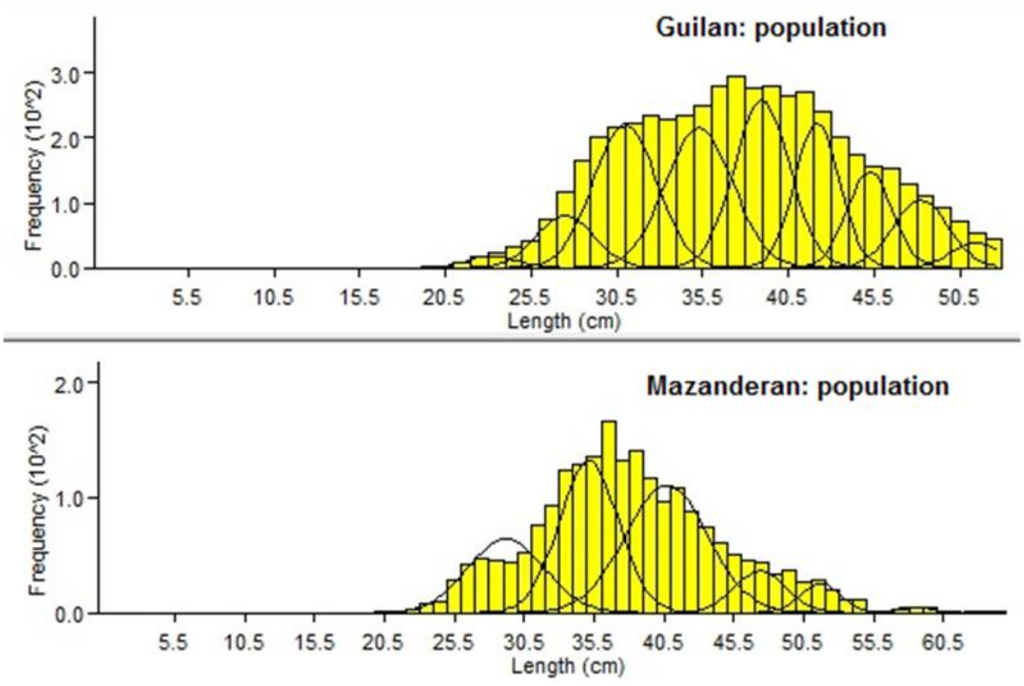

Figure 5. The sequences of operation in the use of the Bhattacharya method of separating a length–frequency distribution into normal components for Caspian kutum from southern Caspian Sea (2017-2018).

based on age composition data, corresponding to the slope of the descending limb of the catch curve, is presented in Figure 6. Estimated instantaneous total mortality rates (*Z*) were 1.32 year^{-1} and 0.63 year^{-1} for males and females of Guilan, respectively, that of males in Mazanderan was 1.04 year^{-1} and of females 0.86 year^{-1}. Instantaneous natural mortality rates (*M*) using the equation of Pauly (1980) was 0.48 year^{-1} for males and 0.26 year^{-1} females in Guilan. The *M* parameter was found to be as 0.54 year^{-1} and 0.45 year^{-1} for males and females caught in fishing ground of Mazanderan. The exploitation ratio (*E*) was found

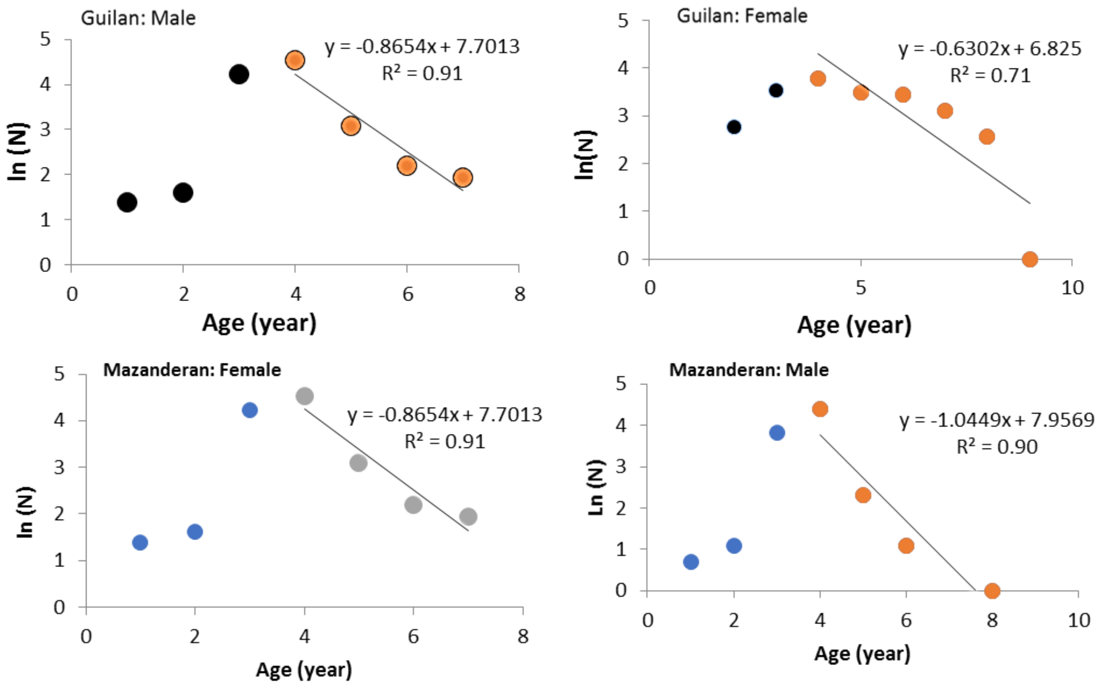

Figure 6. Linearized catch curve of the Caspian kutum and the regression equation obtained- southern Caspian Sea (2017-2018).

to be higher than 0.5 for both sexes of Caspian kutum from Guilan, and to be lower than the expected optimum level of exploitation (*E*=0.50) in Caspian kutum males and females caught in Mazanderan, indicating that Caspian kutum suffered great fishing pressure in Guilan sea areas, and fishing pressures on the Caspian kutum in Mazanderan sea areas have been relatively low.

Discussions

As a comprehensive study on growth parameters of Caspian kutum in the southern Caspian Sea can still be considered as limited to date, the present study provides a more detailed insight into the information on growth of this species. Estimates of demographic growth parameters are important in a broader context as they provide a fundamental description of the life history characteristics. The determination of age and growth is of great importance to both fisheries biology and management as it forms the basic knowledge required for the estimation of mortality, recruitment and yield (Mehanna, 1996).

The size frequency used in the present study, on which growth and mortality estimates depended, were not based on a scientific sampling schedule but rather on random subsamples taken from commercial catches. Fishing gear selectivity is an important consideration in studies determining demographic characteristics of fish populations. Here, the nets used in the beach-seine fishery were selective for the Caspian kutum. Furthermore, the catching this species in the study area was seasonal, which was not caught year-round (Hasanpour et al., 2016). Therefore, this study lacks data some lengths and ages. Irrespective of this selectivity, this study was able to develop growth protocols, provide representative population parameters and mortality rates of this important exploited species. In this study, specimens were successfully aged using scales, shown to be problematic for some Caspian cyprinids in previous studies. In general, scales were hard to read due to the existence of numerous annuli. This is relatively often an important source of error in ageing Cyprinids. It is unlikely that our scale ages represent the true age of the Caspian kutum, despite the fairly precise age estimates achieved by multiple readers using scales.

The two data sets used to assess the Caspian kutum populations' growth variability in the present study were collected approximately within the same time period, and we assume that the pool specimens' data represents the average stock composition. Although it is difficult to compare size and length data among the various studies because of seasonal differences and methods of collection, length frequency analysis applied to the Caspian kutum from the study areas revealed that the stocks of the species consist of different sizes groups. This might be explained by the fact probably stemming from fishery selections on the populations.

Length-weight relationships provided a good fit to data for the Caspian kutum, while there was a great deal of individual variability for the populations. This variability could be attributed to greater differences in size selectivity and/or condition factors among individuals of this species. The length–weight relationship equations had *b*-values significantly differ from "3" reflecting an allometric mode of growth for the Caspian kutum. The allometry coefficient of the length-weight relationship shows positive allometric growth for the population from Mazanderan (>3) and negative mode for the Guilan (<3) populations. However, the *b*-values lie still between the expected range of 2.5–3.5 (Bagenal and Tesch, 1978). The estimated exponent value for female population from Guilan and male population from Mazanderan shows that the fish body is close to the isometric growth model, i.e. body weight increases approximately three times faster than body length. According to Froese (2006), if b=3, then small specimens in the sample under consideration have the same form and condition as the large specimens. Patimar et al. (2009) noted that a variation in *b*-values among populations can be affected by the geographic location as well as the environmental conditions. The difference in the exponents of Caspian kutum could be attributed to the different sampling areas as well as the differences in number of specimens and length ranges of the populations belong to distinct regions (Patimar et al., 2009).

The present *b*-value of Caspian kutum is more or less than those reported by previous studies; Abdolmaleki et al. (2007) gave *b*=3.04, while in Aghili and Mohammadi (2011), 2.96 in the southeastern Caspian Sea and Fazli et al. (2012) reported 3.12 for this species, which all differ from the present ones. These differences in *b*-values could probably be explained by the catches being through several different seasons or they could be attributed to different size distribution, as well as to differences in age composition in different years.

Estimates of von Bertalanffy (VBGF) growth parameters indicated that females reach a larger asymptotic size than males. The larger asymptotic length for females could be attributed to their relatively longer longevity and greater absolute growth rate. The longer lifespan and larger size of females could be considered a life history strategy for supporting increasing egg production (Roff, 1983). The values of L_∞ which are lower than the maximum FL should be accepted considering that no male and female longer than these asymptotic sizes were caught. The estimated VBGF parameters show significant differences between sexes and areas as well, which can be attributed to inter- and intra-population variation of Caspian kutum. Growth parameters (L_∞, K and t_0) are the basic input data into various models used for managing and assessment the status of the exploited fish stocks, these parameters facilitate the comparison between growth of populations belonging to the same species at different times and different localities. Comparison of VBGF parameters from different populations in the southern Caspian Sea, despite differences in methodology and data quality, showed that the growth patterns were different. In the previous studies, growth parameters estimated for combined genders of Caspian kutum were L_∞=70.1 cm FL, k=0.38 per year, and t_0=-1.56 years (Ghaninezhad et al., 2004), L_∞=60.70 cm FL, k=0.15 per year, and t_0=-1.75 years (Abdolmaleki et al., 2007), and L_∞=58.00 cm FL, k=0.24 per year, and t_0=-0.16 years (Hosseini et al., 2010). The difference is may be due to the difference in the ecological parameters in different localities, or the maximum observed lengths in the catch or the methods used in calculations by different authors. We did not find any studies describing weight-based growth parameters of von Bertalanffy for the Caspian kutum. Because of the lack of this kind of data, the parameter W_∞ might not be well-discussed in this study.

For fishes that grow according to the von Bertalanffy function, the VBGF parameters cannot be directly used to compare growth rates among populations, there is practical problem that none of its parameters have the dimensions of growth. The growth performance index (Ø′) emerges as an alternative (Munro and Pauly, 1983; Pauly and Munro, 1984). The relation between $(ln)k$ and $(ln)L_\infty$ turns out to be a consequence of the so called Beverton and Holt dimensionless life-history invariants (Beverton and Holt, 1959; Beverton, 1992; Charnov, 1993), which allows the comparison of growth performance as represented by the Ø′ index (Munro and Pauly, 1983) of stocks of the same species. It also represents a potential check for the accuracy of growth parameter estimates. Comparison of Ø′ calculated using reported VBGF parameters revealed that small difference is in this index among populations, ranging from 6.3 to 7.5. This confirms the accuracy of the calculations, and different VBGF parameters seem to indicate differences in dynamics status of the Caspian kutum populations.

Higher total mortality (Z) and natural mortality (M) for males suggest that the higher survival rate of females may be due to mechanisms developed for perpetuation of the species. Due to direct fishing interest, Caspian kutum is an important species in terms of fisheries management in southern Caspian Sea. Therefore, large difference between the estimates of mortality rates for different populations in the basin indicates a different and variable natural and fishing mortalities. The total and natural mortality rates of Caspian kutum estimated in the present study were larger than those estimated previously in the southern Caspian Sea (Z=0.83 per year and M=0.31 per year for sexes combined population) (Abdolmaleki et al., 2007). This could potentially be due to a combination of factors including (i) the previous estimates were made potentially prior to any significant fishery-associated impacts, and (ii) the effects of sustained levels of harvesting of the species in our study area. Nevertheless, the values of M seem reasonable, considering the biological features of Caspian kutum. The same species may have different natural mortality rates in different areas (Sparre et al., 1989).

The estimate of the exploitation rate (E) indicates a relatively low fishing pressure in Mazanderan fishing areas; this should be treated with caution as mortality rates were estimated from a single sampling season and may be biased due to annual differences in year-class strength. It is generally recommended that assessment studies incorporate a range of mortality estimation methods as a precautionary approach and to improve certainty, particularly in data-poor fisheries as studied here. In Guilan fishing grounds, at the same time, the exploitation rate (E) of the Caspian kutum exceeded an optimally exploited value (Gulland, 1971), indicating that the stocks had been overfishing. Therefore, an urgent fisheries management response is required o prevent the collapse of the Caspian kutum stocks in Guilan fishing areas and to achieve sustainability. In addition, these results could be underestimated because of the lack of illegal catch information and other gear in current use, which may include a significant portion of undersized Caspian kutum.

In conclusion, the present study provides new information about mortality and growth parameters of Caspian kutum, needed for stock assessment and management. However, further research is necessary to elucidate if the relatively high degree of variability found in some of growth parameters could represent either adaptations to local selective pressures (both fishery and environmental) or ecophenotypic variations. The estimated Caspian kutum population parameters indicated a trend toward its being a *k*-strategist species based on high maximum theoretical length, low growth rate, long lifespan and low natural mortality. This indicates that the regulation strategies developed for the fishery management should be based on the Caspian kutum's different growth patterns.

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