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Stocks Status of Kilka in Iranian Waters of the Caspian Sea

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Abstract

The present study considered the situation of kilka stocks using overfished biomass threshold, fishing effort ratio and fishing mortality proxy during 1991-2010. The CPUE index of anchovy kilka and mixed-species (three species of Kilka) indicated no overfishing from 1991 to 2000. In 2000, the CPUE ratio neared the “in danger” region, and subsequently fell into the “overfished” region from 2001 to 2007 for both anchovy and mixed-species of kilka. The CPUE ratios of common kilka have been in an overfished state during 1991-2003. During 2008-2010 the biomass increased and the CPUE ratio of common kilka and mixed-species upgraded to non-overfished region. The control rule of anchovy kilka showed that overfishing was occurred from 1998 to 2010, and overfishing-effort was exceeded the overfishing threshold (MFMT) by 12-66%. The trajectory of the phase-plot of biomass proxy (CPUE ratio) and fishing mortality proxy (effort ratio) of anchovy kilka showed that the status of the fishery of anchovy kilka has generally reduced since 1998 and collapsed to the lowest level in 2010. The trajectory for common kilka has generally increased since 1991 getting close to the fisheries management target in 2007. In conclusion, in the new condition, common kilka is the main species in the Caspian Sea. For stock recovery of anchovy kilka, the catch of three species of kilka must be restricted during reproduction periods, and also, a coordinated international effort should be put into effect.

Keywords: Overfished biomass threshold, Fishing effort ratio, Fishing mortality proxy, Kilka, Caspian Sea

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1. Introduction

The Caspian Sea is the largest inland water body (with no connection to world oceans) in the world, occupying a deep depression on the boundary of Europe and Asia with a water level at present of approximately 27 m below the level of the world oceans (CEP, 2002).

The most abundant fishes of the Caspian Sea are three small clupeids known as "kilka". These include the common kilka (*Clupeonella cultriventris caspia* Bordin, 1904), anchovy (*C. engrauliformis* Svetovidov, 1941) and bigeye (*C. grimmi* Kessler, 1877) (Svetovidov, 1963). Kilka fisheries are important sources of income and protein for Iranian people residing in coastal areas of the Caspian Sea. The collapse of kilka fisheries will have adverse effects both on the economy and regional protein consumption. Annual catches of kilka fishes in the Caspian Sea reached the highest level of about 423 thousand mt in 1970 (Ivanov, 2000). At that time, kilka constituted about 70% of the total fish catch in the basin (Sedov *et al*., 1997).

Kilka species are important food for sturgeons (59.4% by weight of sevryuga diet in the Middle Caspian), Sander (Percidae) and herrings and the Caspian seal. Predators consume 590 million kg of the three kilka species which themselves are the main consumers of zooplankton. Kilka are very important food item in the life of the Caspian Sea (Badalov, 1972; Prikhod'ko, 1979).

During the past 30 years the environmental status of the Caspian Sea has changed significantly in response to impacts of various factors, such as fluctuations in sea level, pollution from different toxicants (Ivanov 2000; Salmanov 1999), invasive species and overfishing (Mamedov, 2006; Daskalov and Mamedov, 2007; Fazli *et al*., 2007; Fazli *et al*., 2009a,b).

In the recent studies kilka stocks were assessed with respect to their biomass and fishing mortality rate, or proxies of those measures. The biomass that produce maximum sustainable yield (B_{MSY}), historically was treated as a target, but that has been found to be insufficiently conservative because of numerous ecological, social and political ambiguities and uncertainties. The objective of the present study is to consider and define the situation of kilka stocks in the last decade using some biomass reference values such as overfished biomass threshold, fishing effort ratio and fishing mortality proxy.

2. Materials and Methods

The kilka examined in this study were caught in the fishing regions in the Iranian Provinces of Mazandaran (with two sampling locations: Amir-abad and Babolsar harbors) and Guilan (with one sampling site: Anazali port) at depths ranging from 30 to 100 m by conical lift-nets equipped with underwater electric lights. Total catches of kilka by each vessel during the night were recorded in kilograms and the density index (catch per unit of effort, CPUE), was calculated as the catch of vessel per night (during 1991-2010; Fig. 1). The annual changes in catch (mt) of three species of kilka in Iranian waters of the Caspian Sea (Fig. 2) were used as input data.

Reduction of populations to B_{MSY} or B_{OY} (optimum yield), by fishing at target rates of F_{MSY} or F_{OY}, has the potential to significantly compromise their integrity (Heinemann *et al*., 2005). More importantly, this damage happens with even lower levels of fishing pressure.

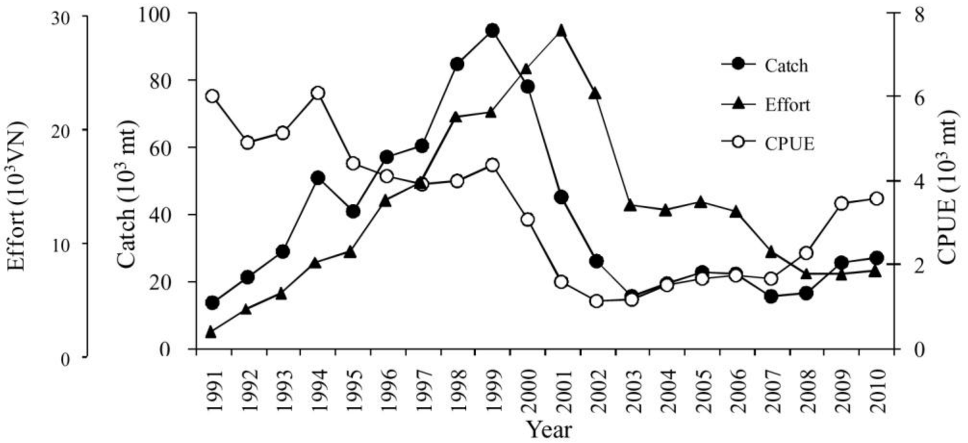

Figure 1. Annual changes in total catch, effort and CPUE of kilka in Iranian waters of the Caspian Sea (1991-2010).

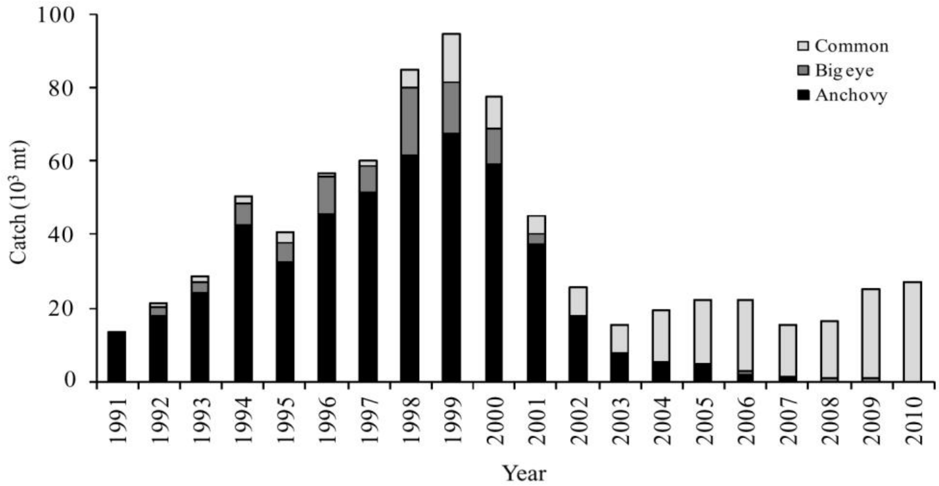

Figure 2. Annual changes in catch (mt) of three species of kilka in Iranian waters of the Caspian Sea (1991-2010).

According to Heinemann *et al*. (2005) the control rule is used in the following manner. First, one or more joint values for the CPUE and Effort Ratios are plotted on the graph; each joint value would represent the state of the complex (biomass proxy) and fishery (fishing mortality proxy) in a given year. The graphical form of the rule then shows that values below the MFMT (Maximum Fishing Mortality Threshold) line represent stocks that are not being overfished, while those above the line are being overfished. Values to the left of the Minimum Stock Size Threshold (MSST) indicate that stocks are overfished, and values to the right indicate stocks are not overfished. Values in between the MSST line and the dash-dot line indicate stocks are in danger of being overfished. The graph can be divided into four quadrants representing regions of CPUE-Effort values that correspond to conditions in which A) the complex is not overfished and not experiencing overfishing, B) the complex is not overfished but is experiencing overfishing, C) not overfished but experiencing overfishing, and D) overfished and experiencing overfishing; two other regions are: C') in danger of being overfished but not experiencing overfishing, and D') in danger of being overfished and experiencing overfishing (Fig. 3, Heinemann *et al*., 2005).

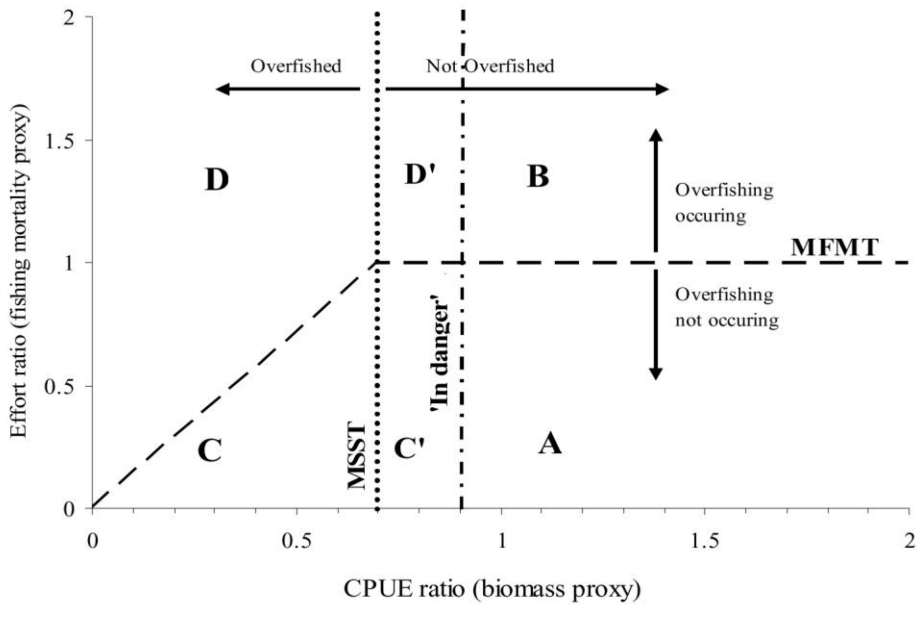

Figure 3. General form of the control rule selected for management and assessment. The lines defining the Maximum Fishing Mortality Threshold (MFMT; dash) and the Minimum Stock Size Threshold (MSST; round-dot) are used to indicate whether a stock is overfished and/or experiencing overfishing, respectively. The dash-dot defines a threshold, below which, but above MSST, a stock is considered in danger of being overfished.

The Schaefer (1954) and Fox (1970) production models, which assume logistic and Gompertz population growth, respectively, were used to determine MSY and the fishing intensity at MSY, f_{MSY}. The equation of the Schaefer model for variance proportional to f^2_t is a simple linear regression equation:

$$\frac{Y_t^*}{f_t} = U_\infty - [\frac{U_\infty q}{r}] f_t + \varepsilon_t$$

where Y^*_t is the equilibrium yield in year t, U_∞ is an asymptotic CPUE, q is a catchability coefficient, r is an the intrinsic natural growth rate, f_t is the fishing effort in year t and ε_t is random error in year t. The Fox model equation, assuming a multiplicative error structure with variance proportional to f^2_t becomes

$$\ln \frac{Y_t^*}{f_t} = \ln U_\infty - \frac{q}{r} f_t + \varepsilon_t$$

which is also in the form of a simple linear regression equation. Total catches and CPUE data from the Iranian conical lift-net fisheries were used as input data. The annual index of total fishing effort was calculated by dividing total catch by CPUE.

3. Results and Discussion

Through fitting fishing effort and CPUE data for anchovy and mixed kilka to the Schaefer production model, the coefficient of determination (R^2) were estimated at 0.646 ($P<0.013$) and 0.64 ($P<0.014$), respectively. Similarly when these data were fit to the Fox (1970) model, R^2 were 0.431 ($P>0.124$) and 0.431 ($P>0.099$), respectively. Hence, at $\alpha=0.05$ the Schaefer model was statistically significant but the Fox model was not. The MSY value for anchovy kilka and mixed species from the Schaefer model was estimated to be 44,652 mt and 59,410 mt, and the fishing intensity needed to achieve MSY was calculated to be 18,609 and 21,074 VN. For common kilka with the Schaefer (1954) production model, the coefficient of determination was 0.845 ($P<0.002$) and for the Fox (1970) model the coefficient of determination was 0.873 ($P<0.001$). Thus, the Fox model was statistically more significant. The MSY value for common kilka from the Fox model was estimated to be 17,870 mt, and the fishing intensity needed to achieve MSY was calculated to be 8,080 VN (Tab. 1). For bigeye kilka both models were not statistically significant at $\alpha=0.05$.

Table 1. Kilka assessment reference values using Schaefer and Fox models

Species	Model	MSY (tons/yr)	CPUE at MSY (tons/yr)	Effort at MSY (vessel×night)
Anchovy kilka	Schaefer*	44652	2.40	18609
	Fox	-	-	-
Common kilka	Schaefer*	-	-	-
	Fox	17870	2.21	8080
Mixed-species	Schaefer	59410	2.82	21074
	Fox*	-	-	-

For big eye kilka both of models are not statistical significantly at α=0.05, *shows the model has statistically more significant and values were accepted.

To establish the ecological sustainability in fish harvests, the estimated MSY and the corresponding effort level were compared with actual catch and effort figures. Obviously, a fishery is not sustainable if total catch exceeds the MSY level. In this study, the catch of anchovy and mixed-species of kilka exceeded MSY from 1997 to 2000 (Fig. 4). The maximum catch of anchovy and mixed-species of kilka was occurred in 1999 and exceeded by 22,800 mt (51.1%) and 35,400 mt (59.9%), respectively. The catch of common kilka exceeded MSY from 2005 to 2006 and 2009 to 2010 (Fig. 4). After *Mnemiopsis leidyi* species (new invader) impacted the Caspian Sea, the stocks of anchovy and bigeye kilka collapsed (Karpyuk *et al*., 2004; Fazli, 2007; Fazli *et al*., 2009a,b), and then the fishing regions shifted from deeper waters (more than 60 m) to lower depth (less than 60 m), where the stock of common kilka is located. Therefore, it is one of the main reasons of common kilka catch increase in Iranian waters during the last decade. Also, Karpyuk *et al*. (2004) reported that, after the *Mnemiopsis leidyi* invaded the Caspian Sea, only the stock of common kilka remained stable and according to Fazli *et al*. 2007, the biomass of common kilka increased by a factor of about 2. In fact, in the new condition, common kilka is the main species of kilka catches.

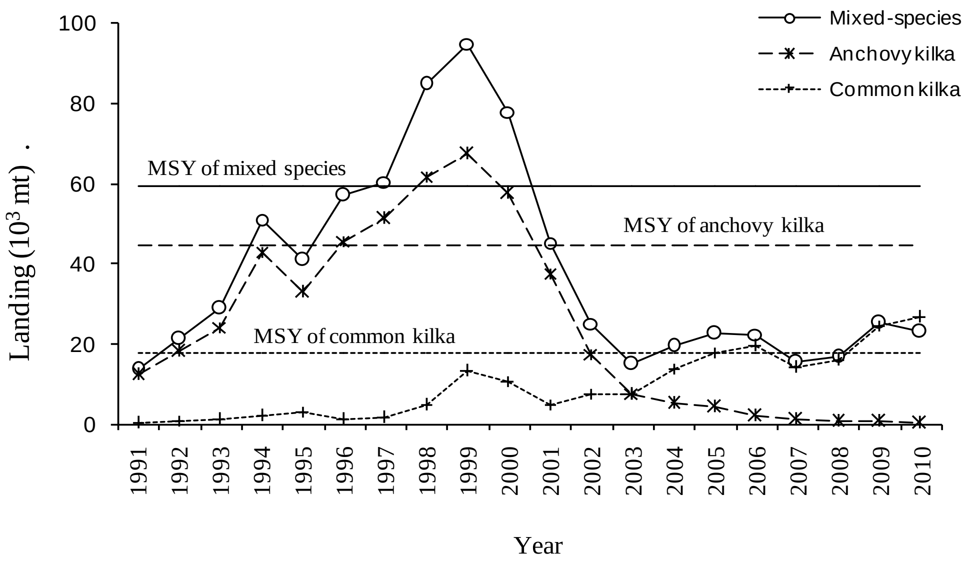

Figure 4. Anchovy, common and mixed-species kilka landings in Iranian waters from 1991-2007, with MSY (Maximum Sustainable Yield) level as a reference (dash line for anchovy kilka, dot line for common kilka and solid line for mixed-species of kilka).

The CPUE estimates indicate that both anchovy kilka and mixed-species have been in an overfished state for 8 of 20 years (Fig. 5); the index indicated no overfishing from 1991 to 2000. It appears that the biomass has remained fairly stable from 1991-1994. During 1995-1999 the biomass declined. However, these estimates provide evidence that the biomass of anchovy and mixed-species of kilka has been above the overfished threshold during 1991-1999. In 2000, the CPUE ratio declined to close to the "in danger" region, and subsequently collapsed to "overfished" region from 2001 to 2007 for both anchovy and mixed-species of kilka. In 2007, the CPUE ratio of anchovy kilka declined to the lowest level, from about 55 times the MSY reference value in 1991. The CPUE ratio of mixed-species had an increasing trend after 2002 but is located in overfished region until 2007. Dissimilar to the anchovy and mixed-species of kilka, the CPUE ratio of common kilka has been in an overfished state during 1991-2003. During 2008-2010 the biomass increased and the CPUE ratio of common kilka and mixed-species moved to not overfished region (Fig. 5).

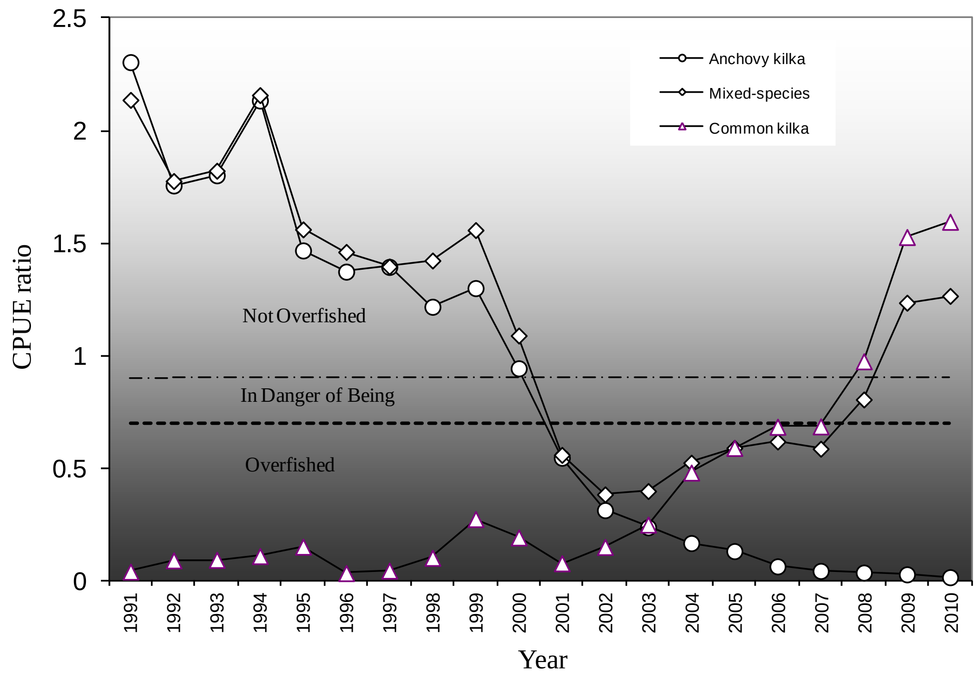

Figure 5. Anchovy, common and mixed-species of kilka CPUE estimates (the biomass proxy) in Iranian waters from 1991-2010. The dash and dash-dot lines are the "in danger of being overfished" and "overfished" thresholds.

Applying the control rule to data of anchovy kilka form 1991-2010 showed that overfishing was occurred from 1998 to 2010 (Fig. 6). During this period of intense overfishing-effort was exceeded the overfishing threshold (MFMT) by 12-66%. For common kilka overfishing was occurred during 1991-2007 but from 2008 it fell below the threshold (Fig. 7). For mixed-species of kilka, it is apparent that overfishing was occurred during 1999-2006. In 2007, the effort fell bellow the threshold (Fig. 8).

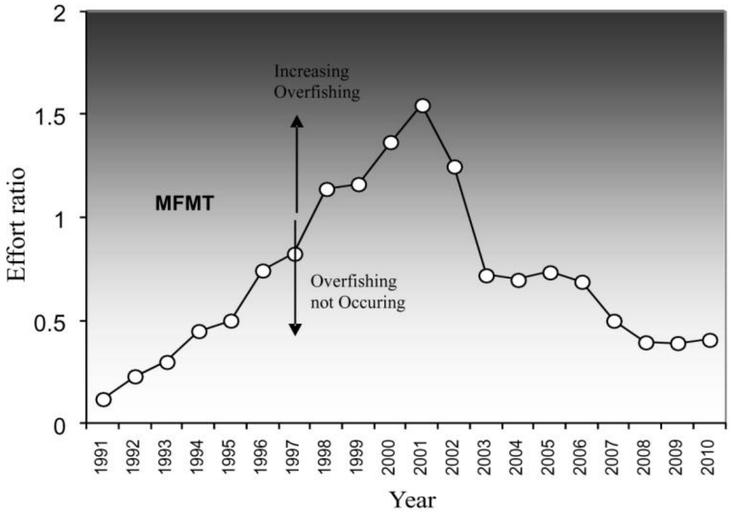

Figure 6. Fishing effort ratio (proxy for current fishing mortality rate relative to the reference value) of anchovy kilka in Iranian waters. Overfishing was occurring in the grey region of the graph and not occurring in the white region; the boundary between the two is the MFMT (Maximum Fishing Mortality Rate) from the Control Rule.

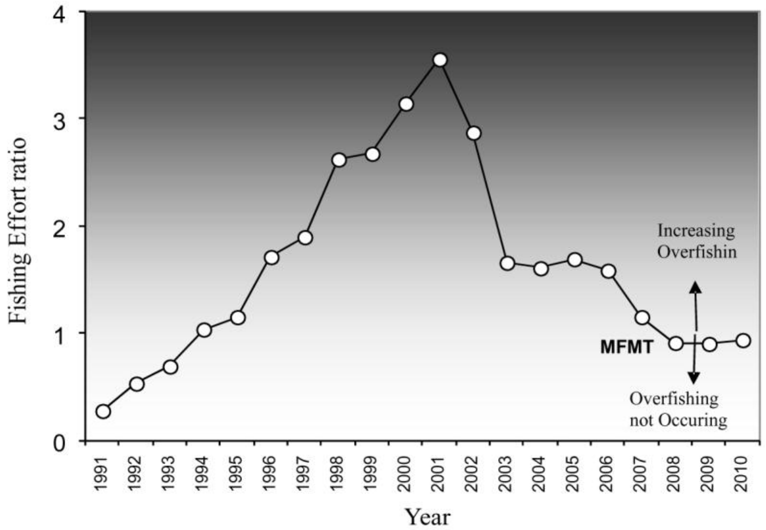

Figure 7. Fishing effort ratio (proxy for current fishing mortality rate relative to the reference value) of common kilka in Iranian waters. Overfishing was occurring in the grey region of the graph and not occurring in the white region; the boundary between the two is the MFMT (Maximum Fishing Mortality Rate) from the Control Rule.

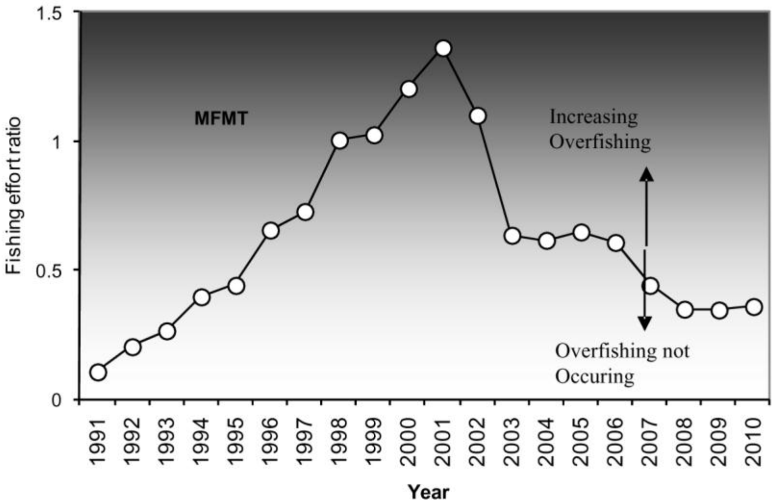

Figure 8. Fishing effort ratio (proxy for current fishing mortality rate relative to the reference value) of mixed-species of kilka in Iranian waters. Overfishing was occurring in the grey region of the graph and not occurring in the white region; the boundary between the two is the MFMT (Maximum Fishing Mortality Rate) from the Control Rule.

The trajectory of the phase-plot of biomass proxy (CPUE ratio) and fishing mortality proxy (Effort ratio) of anchovy kilka from 1991 to 2010 (Fig. 9) showed that the status of the fishery of anchovy kilka has generally declined since 1998 collapsed to the lowest level in 2010 (the right hand side of the plot). Dissimilar to anchovy kilka, the trajectory for common kilka has generally increased since 1991 (Fig. 10). The stock was close to the fisheries management target in 2007, and it has the best situation during 2007-2010. For mixed-species of kilka the status of the fishery declined from 1999 to 2003. In 2008, the stock complex fell to the near “in danger” region and it has been in the best situation during 2009-2010 (Fig. 11).

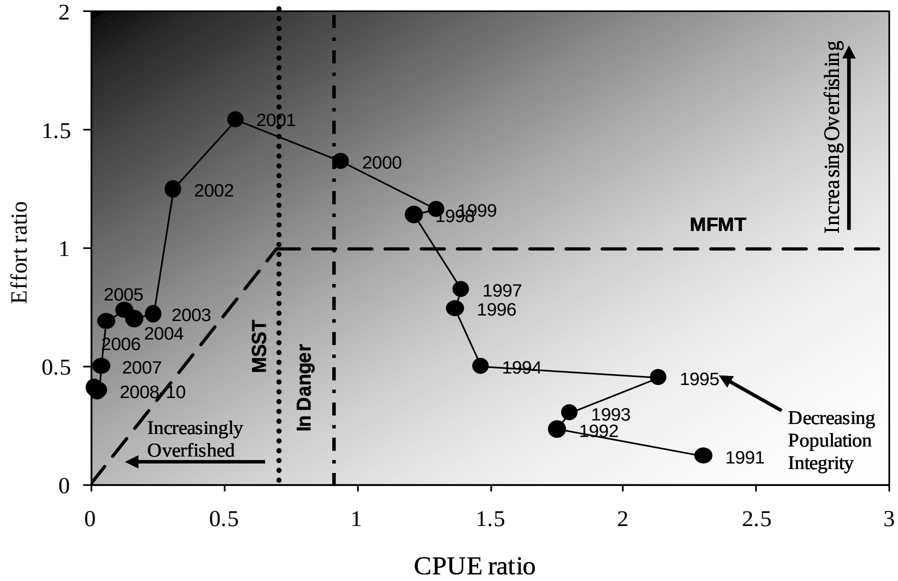

Figure 9. Phase plot showing the trajectory of anchovy kilka in Iranian waters in terms of the biomass proxy (CPUE ratio) and fishing mortality proxy (Effort ratio) from 1991 to 2010.

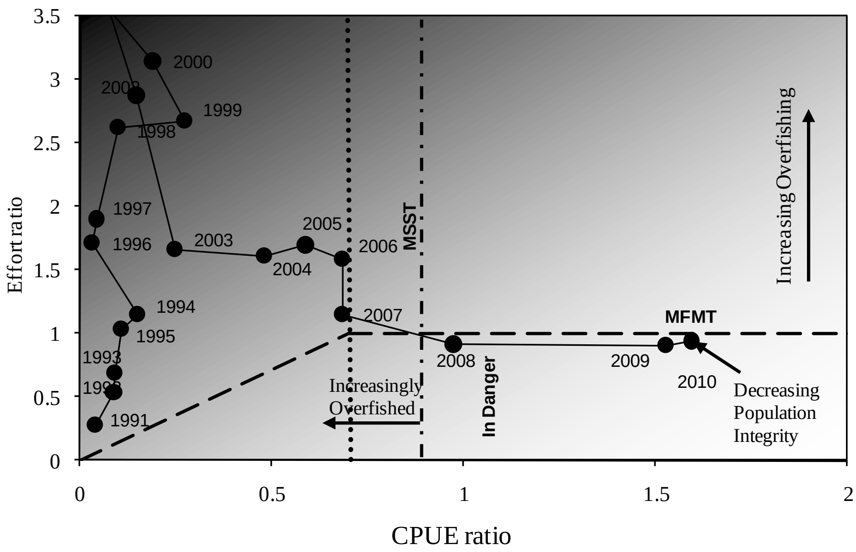

Figure 10. Phase plot showing the trajectory of the common kilka in Iranian waters in terms of the biomass proxy (CPUE ratio) and fishing mortality proxy (Effort ratio) from 1991 to 2010.

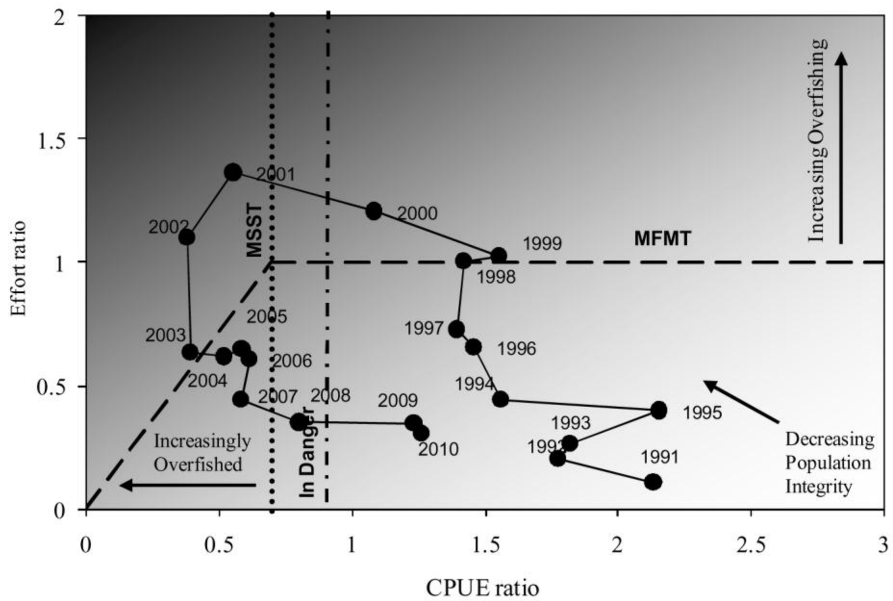

Figure 11. Phase plot showing the trajectory of the mixed species of kilka in Iranian waters in terms of the biomass proxy (CPUE ratio) and fishing mortality proxy (Effort ratio) from 1991 to 2010.

These changes in kilka stocks can be explained as follows. According to several recent reports, the invasive ctenophore (*Mnemiopsis leidyi*) caused the collapse in the stock of anchovy kilka in the Caspian Sea (Karpyuk *et al*., 2004; Kideys and Moghim, 2005; Kideys *et al*., 2005). The explanation for the collapse is a competitive interaction: *Mnemiopsis leidyi* is a voracious predator on zooplankton that is the food for the zooplanktivorous kilka species (*Clupeonella* spp). Sea level change in the Caspian Sea is a natural long-term cyclical process and Fazli (2011) reported that the total catches of kilka have significantly declined since 1983 when the sea level increased. He concluded that during 2000-2009, overfishing as well as various negative impacts resulting from the introduction of *Mnemiopsis*, has resulted in the collapse of the two main species of kilka stocks in the Caspian Sea. During this period, an increase in the biomass of common kilka occurred concurrently with a sharp decline in biomass of anchovy and bigeye kilka and changes in zooplankton abundance and composition, especially an increase in the zooplankton species which are used by common kilka. It seems that the rising sea level has resulted in an expansion of the common kilka spawning areas.

4. Conclusion

In conclusion, in the new condition, common kilka is the main species of kilka catches in the Caspian Sea but the catch of common kilka has exceeded MSY from 2009-2010, and this fishery is not sustainable anymore. Evidently, for sustainability of the species, the catch of common kilka should never exceed the MSY. According to the present study, because of the critical situation of anchovy kilka stocks and also its importance in the whole Caspian ecosystem and as a fishery source, for stock recovery of anchovy kilka, the catch of three species of kilka must be restricted during reproduction periods, and also (according to Daskalov and Mamedov 2007) a coordinated international effort should be put into place to provide a sound management of the fishery activities in the whole Caspian Sea.

References

Badalov, F.G., 1972. The food of *Clupeonella delicatula* (Nordm.) and *C.engrauliformis* (Borodin) in Bol'shoy Kyzylagach Bay in the Caspian. Journal of Ichthyology. 12(6), 1027-1030.

CEP, 2002. Caspian Sea transboundary diagnostic analysis, Caspian Environment Program, 2, 128p.

Daskalov, G.M., and Mamedov, E.V., 2007. Integrated fisheries assessment and possible causes for the collapse of anchovy kilka in the Caspian Sea. ICES Journal of Marine Science. 64, 503-511.

Fazli, H., 2011. Some environmental factors effects on species composition, catch and CPUE of kilkas in the Caspian Sea. International Journal of Natural Resources and Marine Sciences, 1(2), 75-82.

Fazli, H, Zhang C.I., Hay, D.E., and Lee, C.W., 2009a. Stock assessment and management implications of anchovy kilka (*Clupeonella engrauliformis*) in Iranian waters of the Caspian Sea, Fisheries Research. 100, 103-108.

Fazli, H., Zhang, C.I., Hay, D.E., and Lee, C.W., 2009b. Fishery biological characteristics and changes the annual biomass of bigeye kilka (*Clupeonella cultriventris*) in the Caspian Sea. Asian Fisheries Science. 22, 923-940.

Fazli, H., Zhang, C.I., Hay, D.E., Lee, C.W., Janbaz, A.A., and Borani, M.S., 2007. Population Dynamics and Stock Assessment of Common Kilka (*Clupeonella cultriventris caspia*) in the Caspian Sea. Iranian Journal of Fisheries Sciences. 7(1), 47-70.

Fox, W.W.Jr., 1970. An exponential surplus yield model for optimizing exploited fish populations. Transactions of American Fisheries Society. 90, 80-88.

Heinemann, D., Gillelan, H., and Morgan, L., 2005. Bottom fish fishing in the northwestern Hawai'ian islands is it ecologically sustainable? The Ocean Conservancy. 40p.

Ivanov, P.I., 2000. Biological resources of the Caspian Sea. KaspNIRKH, Astrakhan. 130p.

Karpyuk, M.I., Katunin, D.N., Abdusamadov, A.S., Vorobyeva, A.A., Lartseva, L.V., Sokolski, A.F., Kamakin, A.M., Resnyanski, V.V., and Abdulmedjidov, A., 2004. Results of research into *Mnemiopsis leidyi* impact on the Caspian Sea ecosystem and development of biotechnical principles of possible introduction of *Beroe ovata* for biological control of *Mnemiopsis* population. First Regional Technical Meeting, February 22-23, 2004. Teharan. pp. 44-64. http://www.caspianenvironment.org

Kideys, A.E., and Moghim, M., 2003. Distribution of the alien ctenophore *Mnemiopsis leidyi* in the Caspian Sea in August 2001. Marine Biology. 142, 163-171.

Kideys, A.E., Roohi, A., Bagheri, S., Finenko, G., and Kamburka, L., 2005. Impacts of invasive ctenophores on the fisheries of the Black Sea and Caspian Sea. Oceanography. 18(2), 78-85.

Mamedov, V.E., 2006. The biology and abundance of kilka (*Clupeonella spp.*) along the coast of Azerbaijan, Caspian Sea, ICES Journal of Marine Science. 63, 1665-1673.

Prikhod'ko, B.I., 1979. Ecological features of the Caspian kilka (genus *Clupeonella*). Journal of Ichthyology. 19(5), 27-37.

Salmanov, M.A., 1999. Ecology and biological reproduction of the Caspian Sea. Edited by U.I. Sorokin. Baku.

Schaefer, M.B., 1954. Some aspects of the dynamics of populations important to the management of commercial marine fisheries. Inter-American Tropical Tunas Commission Bulletin. 1, 25-56.

Sedov, S.I., Paritsky, Y.A., Zykov, L.A., and Aseinova, A.A., 1997. The Caspian Sea fishery: present status and prospects of development. P. 457. In: Abstracts of the 1st Congress of Russian Ichthylogyists, September 1997, Astrakhan. VNIRO Press, Moscow.

Svetovidov, A.N., 1963. Fauna of U.S.S.R fishes (Translation from Russian) Vol. II No. 1. IPST, Jerusalem, pp. 209-232.