IJNRMS

International Journal of Natural Resources and Marine Sciences

2011, 1 (2), 157-164

Some Environmental Factors Effects on Species Composition, Catch and CPUE of Kilkas in the Caspian Sea

Hasan Fazli

Caspian Sea Ecology Research Center, Sari, Iran

Received: 16 November 2010 / Accepted: 22 February 2011 / Published Online: 15 August 2011

Abstract This study evaluates changes in species composition, catch, and CPUE of three species of kilkas in the Caspian Sea from 1961 to 2009. The effects of fluctuations in sea level rise and fall on the catch of kilka as well as the impacts of a recent invasion by *Mnemiopsis leidyi* (Ctenophora) were assessed in terms of species composition and CPUE of kilkas in the Iranian coastal region of the Caspian Sea. We found a negative correlation between long-term sea level changes and total catch (R^2 = –0.56; P<0.001, which significantly declined in 1995 when the sea level increased to its highest level. Comparing catch per unit effort (CPUE) values during the pre-invasion (1996–1999) and post-invasion (2000–2009) periods indicated significant declines in anchovy and bigeye kilka, while common kilka increased significantly after the ctenophore invasion. During 2000–2009 overfishing, together with various environmental impacts following the introduction of *Mnemiopsis,* were major factors that contributed to changes in species composition and the collapse of kilka stocks in the Caspian Sea.

Key words: *Caspian Sea, Catch, Invader species, Iran, Kilka, Sea level*

1 INTRODUCTION

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 fishing in the Iranian waters of the Caspian Sea started with six ships in Anzali port in 1970. Until 1976, annual catches were less than 4000 mt (Razavi, 1993). Between the years 1989 and 1998, the number of fishing vessels and fishing activities increased progressively and Iran increased its quota of kilka catches to 95000 mt up until 1999. In the next few years, however, the catch sharply decreased to 19500 mt in 2004 (Fig. 1).

During the past 30 years the environmental status of the Caspian Sea changed significantly due to the impacts of various factors, such as fluctuations in sea level and pollution of various toxicants (Ivanov, 2000; Salmanov, 1999). Recent introductions of invasive species via ballast water from ships have also had a negative impact on fish stocks in the Caspian Sea (Ivanov *et al.*, 2000). In particular, an invasive jellyfish (Ctenophora, *Mnemiopsis leidyi*), which had appeared by November 1999 (Ivanov *et al.*, 2000), affected kilka stocks (Fazli *et al.*, 2007, 2009; Daskalov and

* *Corresponding author: The Caspian Sea Ecology Research Center, Sari, Iran. Tel: +98 151 346 2512. Fax: +98 151 346 2495. E-mail: hn_fazli@yahoo.com*

Mamedov, 2007). The present study documents some vital information gaps on the species composition and catch per unit effort (CPUE) of kilkas and examines the relationship of catch and CPUE with environmental changes with the purpose of investigating the collapse of kilka stocks in the Caspian Sea.

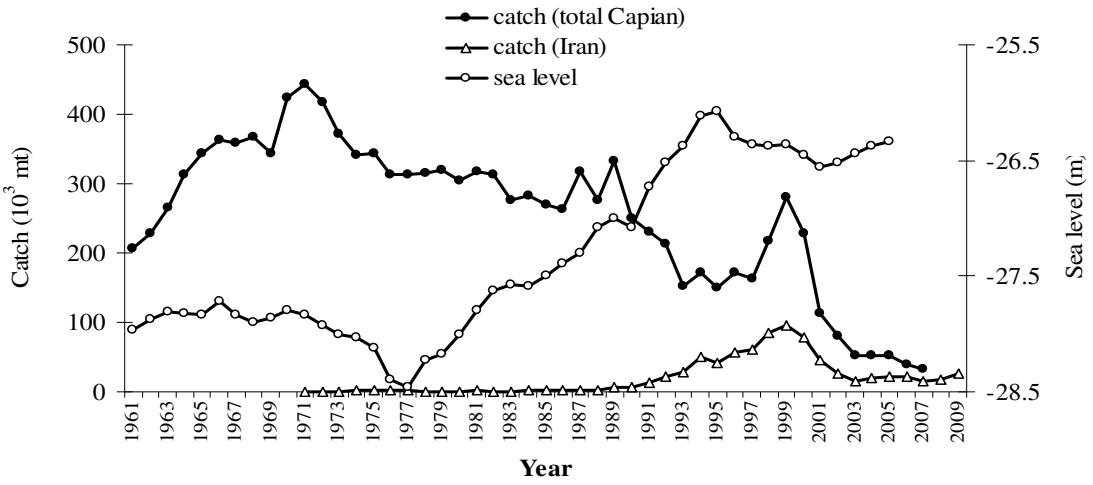

Fig. 1 Annual catches of kilkas in Iranian waters of the Caspian Sea (data source on catches: Fishstat Plus, FAO Fisheries Department, Fishery Information, Data and Statistic Unit; FISHSTAT Plus: Universal software for fishery statistical time series, Version 2.3. 2000).

2 MATERIALS AND METHODS

Sampling areas were located in fishing regions on the Iranian coast: Mazandaran (with two sampling locations), Amir-abad and Babolsar harbors, and Guilan (one sampling site: Anazali port). The kilkas examined in this study were caught by conical liftnets, equipped with underwater electric lights, at depths ranging from 40 to 100 m. The diameter of the hoop of a conical liftnet is generally 2.5 to 3 m, and the mesh size between two knots of the net was 7–8 mm. The size and configuration of the conical liftnets were nearly identical among all fishing vessels, so all ships were equipped with the same basic net. The fishing vessels are small (15–100 tons capacity) and fishing was conducted at night.

The total catch of kilkas by each vessel during the night was recorded in kilograms. The CPUE was estimated as the catch of one vessel per night (vessel×night). Field sampling was conducted by staff of the Caspian Sea Ecology Research Center and the Bony Fishes Research Center. To determine species composition, 3–5 kg of fish were randomly selected every 2 weeks in landing areas during 1996–2004. In addition, data from Janbaz *et al.* (2010) on the species composition of kilka caught between 2005 and 2009 were also used. Environmental factors may affect any stage of the life history to some degree. In the Caspian Sea, the major factors affecting kilka catch are sea level, temperature, and species interactions (The Caspian Sea biodiversity database). In this study, Caspian Sea levels and the invasive jellyfish (Ctenophora, *Mnemiopsis leidyi*) were identified as the potential determinants of CPUE, based on correlation analyses and statistical tests among various environmental factors. Information on total catches of kilkas was accessed from the FAO statistics Unit (FAO Fisheries Department, Fishery Information, Data and Statistic, Fishstat Plus software).

Since the invasive jellyfish had appeared by

November 1999, the CPUE values for enhanced analysis were divided into two times periods: 1996–1999 (pre-invasive) and 2000–2009 (post invasive). Data from each period were compared using a *t*-test to consider the effect of the invasion at the Iranian coasts of the Caspian Sea.

3 RESULTS

Annual catches of anchovy kilka in the Iranian waters of the Caspian Sea increased from 52,246 mt in 1997 to a maximum of 67,450 mt in 1999, but dropped to 4,500 mt in 2009 (Table 1).

The change in the catch of bigeye kilka was even more pronounced, increasing from 6,704 mt in 1997 to 18,500 mt in 1998 and then collapsing to 300 mt in 2009. The catch of common kilka increased from about 1,450 mt in 1997 to 13,015 in 1999, but declined to 4,780 mt in 2001. In 2009, catch of the common kilka was recorded as 24,400 mt. During 1995–2001 the catches of anchovy kilka predominated and ranged from 71.0 to 87.5%, followed by bigeye kilka, ranging from 6.2 to 21.7% and common kilka from 1.8 to 13.7% of total catches by weight. From 2002 onwards, the relative frequency of anchovy and big-eye kilka in kilka catches collapsed, and in 2009 reached levels of 1.8 and 1.2%, respectively. The frequency of common kilka increased and predominated in 2009 (comprising 97% of total catches: Table 1).

The effort required for catches in Iranian coastal waters increased from 4,298 VN (vessel×night) in 1992 to 28,736 VN in 2001 and declined to 7,300 VN in 2009. During the years 1992–1999 the CPUE ranged from between about 4.0 mt to about 6.1 mt/VN, then sharply declined to less than 1.1 mt/VN during 2002 and 2003. In 2009 it increased to 3.4 mt/VN (Table 1).

The monthly species composition of three kilka species caught during the years 1997–2009 in Iranian waters of the Caspian is shown in Fig. 2.

From 1997 to 1998, common kilka was often observed in spring and summer and big-eye kilka was frequently recorded in autumn and winter.

Table 1 Catch, effort, CPUE and species composition of the Iranian kilkas fishery during 1997-2009. VN vessel×night, mt metric tones.

Year	Species						Total catch		Effort
	Anchovy kilka		Bigeye kilka		Common kilka				
	Catch, mt (%)	CPUE, mt/VN	Catch, mt (%)	CPUE, mt/VN	Catch, mt (%)	CPUE, mt/VN	%	mt	VN
1997	52246 (86.5)	3.35	6704 (11.1)	0.50	1450 (2.4)	0.09	100	60400	15344
1998	61880 (72.8)	2.92	18445 (21.7)	0.87	4675 (5.5)	0.22	100	85000	21190
1999	67450 (71.0)	3.12	14535 (15.3)	0.67	13015 (13.7)	0.60	100	95000	21623
2000	57486 (73.7)	2.26	9828 (12.6)	0.39	10686 (13.7)	0.42	100	78000	25407
2001	37590 (83.2)	1.31	2801 (6.2)	0.10	4789 (10.6)	0.17	100	45180	28736
2002	17358 (69.5)	0.75	25 (0.1)	0.00	7592 (30.4)	0.33	100	24975	23215
2003	7530 (50.5)	0.57	89 (0.6)	0.01	7291 (48.9)	0.55	100	14910	13405
2004	5089 (26.9)	0.40	227 (1.2)	0.02	13602 (71.9)	1.06	100	18918	12992
2005	4249 (18.8)	0.31	542 (2.4)	0.04	17808 (78.8)	1.30	100	22600	13676
2006	1896 (8.5)	0.15	1048 (4.7)	0.08	19356 (86.8)	1.51	100	22300	12816
2007	910 (6.0)	0.10	379 (2.5)	0.04	13881 (91.5)	1.49	100	15170	9309
2008	440 (2.7)	0.06	277 (1.7)	0.04	15573 (95.6)	2.13	100	16290	7300
2009	454 (1.8)	0.06	302 (1.2)	0.04	24444 (97.0)	3.35	100	25200	7295
Mean	(43.0)		(6.3)		(49.7)				

During this period, big-eye kilka predominated in February or March and anchovy kilka predominated during other months. In 1999 and thereafter, common kilka had a higher frequency during the whole year and dominated catches from 2003 to 2009. During this period the frequency of bigeye kilka declined sharply to zero. The frequency of anchovy kilka declined in all months during the years 2004-2009.

Monthly change in CPUE of each kilka species in Iranian fishing regions from 1997 to 2009 is shown in Fig. 3. There was a big decrease in the CPUE of anchovy and bigeye kilka during all months in the years of 2002-2009. *T-test* analysis showed significant differences between the monthly CPUE values during the years 1996–1999 and 2000–2009 for both species ($P<0.001$ and $P<0.002$, respectively: Table 2). The CPUE of common kilka increased significantly between two periods ($P<0.001$: Table 2).

The long-term total catch data of kilkas in the Caspian Sea and sea level trends showed that a significant decline in 1995 when the sea level increase was at its peak (Fig. 1). The correlation between sea level and total kilka catch was statistically significant ($R^2 = –0.56$; $P<0.001$).

4 DISCUSSION

Sea level change in the Caspian Sea level is a natural long-term cyclical process. A Caspian Sea level fall (in 1977; Fig. 1) was followed by reduction the sea area (especially of the shallow Northern Caspian), changes in hydrological and hydrochemical regimes (with a salinity increase of up to 11‰), and changes in species composition of the prey hydrobionts, due to a sharp reduction in biomass and a slow increase of halobionts (Ivanov, 2000). Anchovy kilka is the main item of commercial fishing in the Caspian Sea harvested by all littoral states. This species contributed more than 80% of the total catches of kilka in the Caspian basin (Sedov and Rychagova, 1983; Fazli and Besharat, 1998). The greatest abundance of this species was recorded during the period of minimum sea level, 1960–1980 (Sedov and Rychagova, 1983). The Caspian Sea Biodiversity Database (CSBD) reported that the stocks decreased over the last decades of the sea level rise. Common kilka lives in the coastal zone of the sea at depths of less than 50–70 m and is a widely distributed euryhaline species (Prikhod'ko, 1981). The rising sea level, which stared in 1978, resulted in an expansion of the species spawning area and an increased in abundance of the common kilka (CSBD). The present study shows a significant correlation between catch and sea level.

According to Roff and Fairbairn (1980), assessing CPUE levels over time is possibly the best method for assessing changes in abundance and can also be considered as a reasonable measure of population size. Current results indicate that CPUE values from 1997–1999 (prior to the invasion of *Mnemiopsis leidyi* in November 1999; Ivanov *et al*., 2000) to 2000–2009 declined significantly in terms of anchovy and bigeye kilka ($P<0.001$ and $P<0.002$, respectively; Table 2) but CPUE of common kilka increased significantly during the years 2000–2009 ($P<0.001$).

Table 2 Results of a *t*-test on comparison of mean of CPUE (mt/VN) of three species of kilkas during two periods (1997–1999 and 2000–2009) in Iranian fisheries. VN vessel × night, mt metric tones.

Species	During the years 1996–1999			During the years 2000–2009			*t*	P
	n	Mean	SD	*n*	Mean	SD		
Anchovy	45	2.969	1.166	119	0.555	0.709	13.0	0.001
Bigeye	45	0.474	0.807	119	0.080	0.200	3.2	0.002
Common	45	0.219	0.320	119	1.076	1.078	7.9	0.001

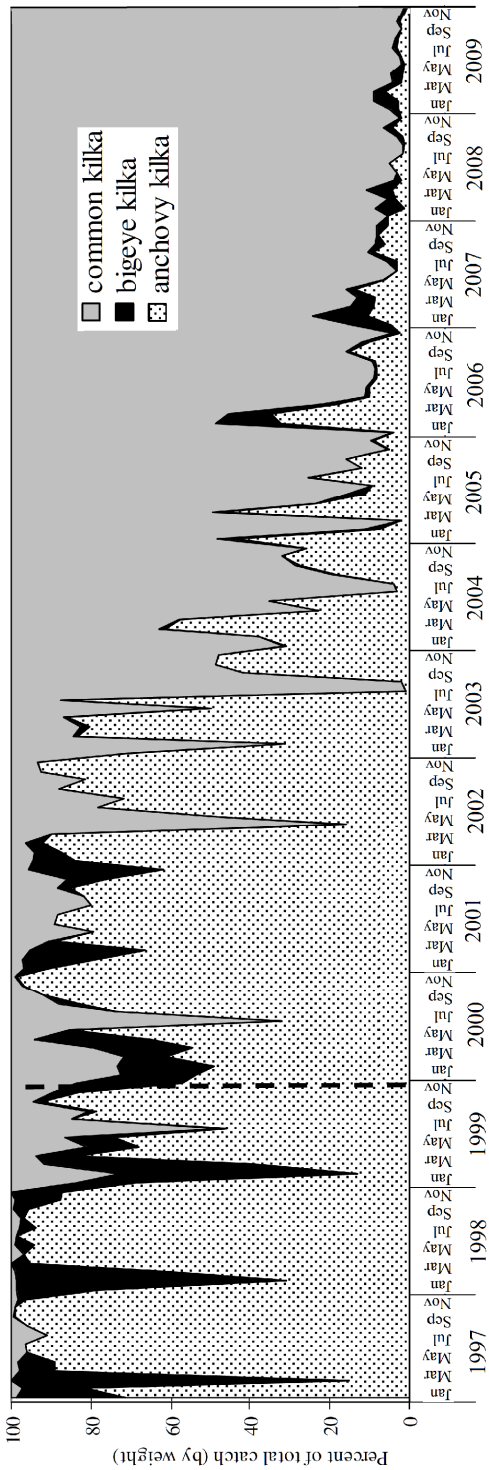

Fig. 2 Monthly percentage composition of kilkas in the catch of the conical liftnet fishery in Iranian waters of the Caspian Sea: 1996–2010.

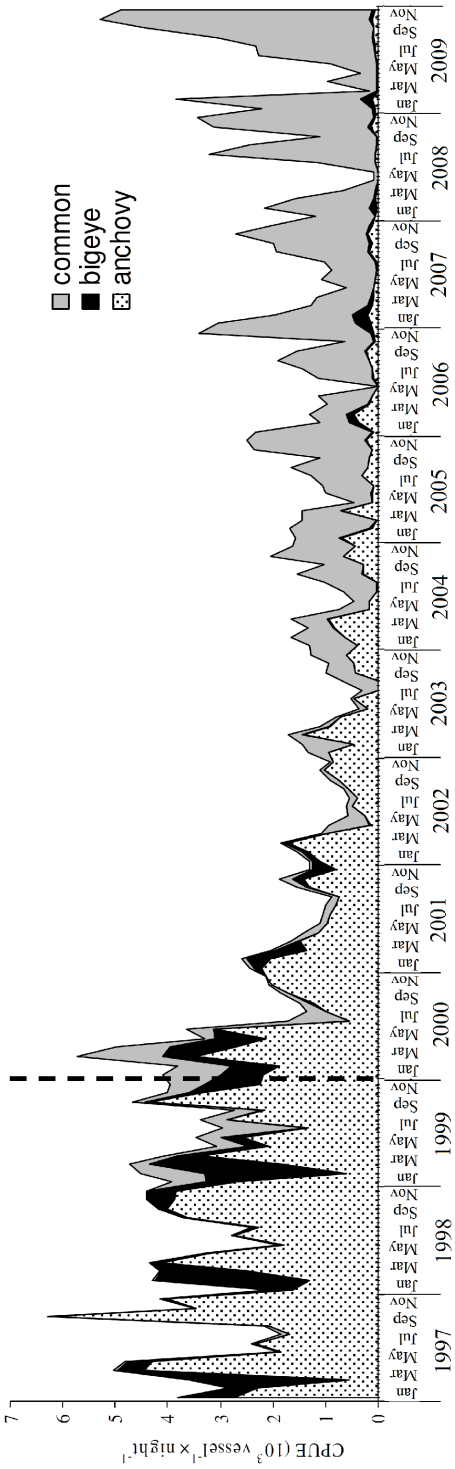

Fig. 3 Monthly CPUE of three kilka species in Iranian waters of the Caspian Sea during 1997–2010. The thick dotted line indicates the first appearance of the ctenophore in the Caspian Sea.

Mnemiopsis is an actively hunting carnivore that feeds on zooplankton (including meroplankton, which comprises the larvae of benthic animals), fish eggs and fish larvae (Tsikhon-Lukanina *et al.*, 1993; Mutlu, 1999). It often feeds superfluously, regurgitating excess ingested food, and it can consume up to ten times its own weight per day (Kremer, 1979). This invasive species has negatively affected pelagic fisheries of the Black and Azov Seas. Fisheries based on zooplanktivorous fish species such as anchovy (*Engraulis encrasicolus ponticus*), Mediterranean horse mackerel (*Trachurus mediterrraneus ponticus*) and sprat (*Sprattus sprattus phalericus*) collapsed in the Black Sea (Ivanov *et al*., 2000). This catastrophic decline was caused by both the elimination of the zooplankton, the normal food of pelagic species, and predation by *Mnemiopsis* on pelagic fish eggs and early larvae (Shiganova and Bulgakova, 2000). The biodiversity of zooplankton in Iranian regions of the Caspian Sea decreased from 29 species in the year 1994 to 12 species in the years 2001–2002. Furthermore, the biomass of these organisms had a significant decrease in summer and autumn, declining to relative levels 2–45 times (as fractions of the original large population) during the years 1998 and 2002, respectively (Rowshantabari and Roohi, 2004; Roohi *et al*., 2008, 2010). According to studies carried out during the summer of 1994, the *Acartia* sp. Copepod comprised 50% of the zooplankton population in the southern Caspian, the rest of the population being comprised mainly of the larvae of bivalve mollusks such as *Lamellibranchiata* larvae. From 2001 onwards changes in the composition of planktonic species were observed, so that by 1994 more than 95% of the zooplankton population in southern Caspian was comprised of *Acartia sp*. In 1994 *Eurytemora* spp. was dominant at depths of more than 20 m, but this species was not present in samples collected during 2001–2002. Karpyuk *et al*. (2004) reported that 90–97% of the food of adult anchovy kilka, the main species of kilka fishery, consists of two copepod species: *Eurytemora grimmi, E. minor* and *Limnocalanus grimaldii* (which comprised 70% of the stomach content). When *Mnemiopsis*, kilka's food competitor, appeared in the Caspian Sea, the species composition of meso- and macrozooplankton in the Middle and Southern Caspian declined drastically. Based on data collected by the KaspNIRKh Laboratory of Hydrobiology, there is evidence that the gross biomass of the main food species of kilka decreased by a factor of 10, and abundance was reduced to 1/50 of their former level. The main food species of anchovy kilka, *Eurytemora* spp. and other copepods were replaced by another member of the copepods, *Acartia* sp., presently the dominant species of mesoplankton. It was concluded that, following the severe impacts of *Mnemiopsis,* only the stock of common kilka remained stable (Karpyuk *et al*., 2004).

In conclusion, the total catches of kilkas have significantly declined since 1983 when the sea level increased. During 2000–2009, overfishing as well as various negative impacts resulting from the introduction of *Mnemiopsis,* the two main species of kilka stocks in the Caspian Sea collapsed. 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 zooplankton species used by common kilka.

5 REFERENCES

Daskalov, G. M. and Mamedov, E. V. Integrated fisheries assessment and possible causes for the collapse of anchovy kilka in the Caspian Sea. ICES J. Marine Sci. 2007; 64: 503–511.

Fazli, H. Population dynamics and stock assessment of kilka (genus: *Clupeonella*) in Iranian waters of the Caspian Sea. PhD thesis, Pukyong National University, 2007; 145 pp.

Fazli, H. and Besharat, K. Stock assessment of Kilka fishes by hydro acoustic method and commercial catch monitoring. Mazandaran Fisheries Research Center (in Farsi). 1998.

Fazli, H., Zhang, C. I., Hay, D. E., Lee, C. W., Janbaz, A. A. and Borani, M. S. Population ecological parameters and biomass of anchovy kilka (*Clupeonella engrauliformis*) in the Caspian Sea. Fish. Sci. 2007; 73(2): 285–294.

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

Janbaz A. A., Kor, D., Moghim, M., Afraei, M. A., Abdolmaleki, S., Daryanabard, G., Bagheri, S., Khedmati, K., Shabani, K., Nahrevar, M. R. and Rastin, R. Biological aspects of Kilka (Age, Growth, Feeding and Reproduction) in southern Caspian Sea. Caspian Sea Ecology Research Center, 2010; 122 p.

Ivanov, P. I. Biological resources of the Caspian Sea. KaspNIRKH, Astrakhan, 2000; 96 pp.

Ivanov, P. I., Kamakim, A. M., Ushivtzev, V. B., Shiganova, T. A., Zhukova, O., Aladin, N., Wilson, S. I., Harbinson, G. R. and Dumont, H. J. Invasion of Caspian Sea by the come jellyfish *Mnemiopsis leidyi* (Ctenophora). Biol. Invas. 2000; 2: 255–258.

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. 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. Tehran. 2004; pp. 44-64. http://www.caspianenvironment.org

Kremer, P. Predation by the ctenophore *Mnemiopsis leidyi* in Narragansett Bay, Rhode Island, Estuaries 2, 1979; 97-105.

Mutlu, E. Distribution and abundance of ctenophores, and their zooplankton food in the Black Sea. II. Mnemiopsis leidyi. Marine Biology 135, 1999; 603-613.

Prikhod'ko, B. I. Ecological features of the Caspian Kilka (Genus *Clupeonella*) Scripta Publishing Co., 1981; pp 27-35.

Razavi, S. On kilka fishing status in the Caspian Sea, Iranian fisheries bulletin, no.2, Spring 1993 pp. (in Farsi). 1993.

Roff, D. A. and Fairbairn, D. J. An evaluation of Gulland's method for fitting the Schaefer model. CJFAS 1980; 37: 1229-1235.

Roohi, A., Zulfigar, Y., Kideys, A., Aileen, T., Ganjian, A. and Eker-Develi E. Impact of a new invader ctenophore *Mnemiopsis leidyi* on the zooplankton of the southern Caspian Sea, *Marine Ecology,* 2008; 29(4): pp. 421-434.

Roohi, A., Kideys, A., Sajjadi, A., Hashemian, A., Pourgholam, R., Fazli, H., Ganjian Khanari, A. and Eker-Develi E. Changes in biodiversity of phytoplankton, zooplankton, fishes and macrobenthos in

the Southern Caspian Sea after the invasion of the ctenophore *Mnemiopsis leidyi,* Biol. Invas. 2010; 12: 2343–2361.

Rowshantabari, M. and Roohi, A. Impacts of *Mnemiopsis leidyi* on zooplankton population in the southern Caspian Sea. First Regional Technical Meeting, February 22–23, 2004. Tehran. 2004; pp. 161–167. http://www.caspianenvironment.org

Salmanov, M. A. Ecology and biological reproduction of the Caspian Sea. Edited by U.I. Sorokin. Baku. 1999; p. 397.

Sedov, S. I. and Rychagova, T. L. Morphological characteristics of anchovy kilka, Clupeonella engrauliformis (Clupeidae), in winter and spring. J. Ichthyol. 1983; 23(3): 140–143.

Shiganova, T. A. and Bulgakova Y. V. Effect of gelatinous plankton on the Black and Azov Sea fish and their food resources. ICES J. Mar. Sci. 2000; 57: 641–648.

Svetovidov, A. N. Fauna of U.S.S.R fishes. Vol. II No. 1 Clupeidae, IPST, Jerusalem. 1963.

Tsikhon-Lukanina, E. A., Reznichenko, O. G. and Lukasheva, T. A. Ecological variation of comb-jelly *Mnemiopsis leidyi* (Ctenophora) in the Black Sea. Zhurnal Obszhei Biologii 1993; 54: 713–724 (in Russian).

اثرات برخی از فاکتورهای محیطی بر ترکیب گونه‌ای، صید و صید در واحد تلاش کیلکا ماهیان در دریای خزر

حسن فضلی

مرکز تحقیقات اکولوژی دریای خزر، ساری، ایران

چکیده در این مطالعه تغییرات در ترکیب گونه‌ای، صید و صید در واحد تلاش (CPUE) سه گونه کیلکا در طی سال-های ۱۳۴۰ الی ۱۳۸۸ در دریای خزر بررسی شده است. روند تغییرات سطح آب دریای خزر روی صید کیلکا ماهیان به همراه ورود یک گونه شانه‌دار مهاجم جدید (Ctenophore, *Mnemiopsis leidyi*) بر ترکیب گونه‌ای و صید در واحد تلاش کیلکا ماهیان در سواحل ایران مورد ارزیابی قرار گرفته است. نتایج نشان داد در یک دوره طولانی مدت بین سطح آب و میزان کل صید کیلکا ماهیان در دریای خزر یک رابطه منفی وجود دارد (R^2 = -۰/۵۶ ؛ P<۰/۰۰۱). زمانی که در سال ۱۳۷۴ سطح آب دریای خزر به بیشترین میزان خود افزایش یافت میزان کل صید کیلکا ماهیان به طور معنی‌داری کاهش یافت. مقایسه مقادیر صید در واحد تلاش کیلکا ماهیان در دو دوره قبل (۱۳۷۸-۱۳۷۵) و بعد (۱۳۸۸-۱۳۷۹) از حضور شانه‌دار مهاجم در دریای خزر نشان داد که مقدار این شاخص برای دو گونه کیلکای آنچوی و چشم درشت به شدت کاهش ولی برای کیلکای معمولی بعد از ورود شانه‌دار مهاجم به طور معنی‌داری افزایش داشته است. به نظر می‌رسد که در طی سال‌های ۱۳۸۸-۱۳۷۹ صید بی‌رویه و همچنین مشکلات اکولوژیکی ناشی از حضور شانه‌دار مهاجم سبب تغییرات در ترکیب گونه‌ای و تخریب ذخایر کیلکا ماهیان در دریای خزر باشد.

کلمات کلیدی: ایران، دریای خزر، سطح آب دریا، صید، کیلکا، گونه مهاجم