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STUDY OF POPULATION DYNAMICS AND BIOLOGICAL PARAMETERS OF ANCHOVY KILKA (*CLUPEONELLA ENGRAULIFORMIS*) IN SOUTHEAST PART OF CASPIAN SEA (MAZANDARAN PROVINCE)

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Population dynamics and biological parameters of anchovy kilka *Clupeonella engrauliformis* have been studied. The age structure of population, length-weight ratio, sex ratio, sexual maturity stages, growth parameters, natural and fishing mortality coefficients have been estimated. It was found that anchovy kilka has gradually decreased in catches during 1997-2008 due to several factors including fishing pressure, invasion of species using the same resource base. It was concluded that alongside with the main factor – fishery, other environmental factors also influence anchovy kilka population and cumulative effect of all the factors may lead to stock depletion.

Growth - sexual maturity stage - Caspian Sea-over-fishing - kilka

Իրականացվել է անչոուսային կիլկայի (*Clupeonella engrauliformis*) կենսաբանական ցուցանիշների և պոպուլյացիոն փոփոխությունների հետազոտում։ Տրվել են պոպուլյացիայի հասակային կառուցվածքի գնահատականը, կշիռ-երկարության և սեռերի հարաբերությունը, հասունացման փուլը, ամի ցուցանիշները, բնական և արդյունագործական մահացության գործակիցները։ Բացահայտվել է, որ 1997-2008թթ. անչոուսային կիլկայի մասնաբաժինը ձկան ընդհանուր որսաչափում արդյունագործական ծանրաբեռնվածությունը ներառող տարբեր գործոնների ազդեցության և սննդառության տեսակետից մրցակիցների ներխուժ- ման արդյունքում աստիձանաբար նվազել է։ Կատարվել է եզրակացություն, որ հիմնական գործոնի՝ արդյունահանման, հետ մեկտեղ, գոյություն են ունեցել նաև այլ գործոններ, որոնք ազդել են անչոուսային կիլկայի պոպուլյացիայի վրա և դրանց կուտակային ազդեցությունը կարող է հանգեցնել կիլկայի պաշարների կոչասոման։

ԱՃ - հասունության փուլ - Կասպից ծով (գերորս (կիլկա

Проведено исследование популяционной динамики и биологических параметров анчоусной кильки (*Clupeonella engrauliformis*). Дана оценка возрастной структуры популяции, соотношения веса-длины, полов, стадий зрелости, параметров роста, коэффициентов естественной и промысловой смертности. Выявлено, что доля анчоусной кильки в уловах 1997-2008гг. постепенно снизилась вследствие различных факторов, включающих промысловую нагрузку, вторжение пищевых конкурентов. Было сделано заключение, что наряду с главным фактором - промыслом, существуют также и другие факторы, влияющие на популяцию анчоусной кильки, и их кумулятивный эффект может привести к подрыву ее запасов.

Рост – стадии зрелости – Каспийское море – перелов – килька

Three species of kilka fishes, belonging to Clupeidae family - anchovy kilka (*Clupeonella engrauliformis*, Svetovidov, 1941), bigeye kilka (*Clupeonella grimmi*, Kessler, 1877) and common kilka (*Clupeonella cultriventris caspia*, Bordin, 1904) are inhabiting in the Caspian Sea. Kilka fishes are pelagic fishes living in schools and are one of the most abundant fishes in Caspian Sea because of feeding on zooplankton. They are considered as Caspian Sea bread as many other aquatic animals feed on them. Distribution of these fishes in the middle and southern Caspian Sea is related to existence of specific sea currents and feeding pattern [1]. All three kilka species are present in commercial catches with use of under-water electric lights and fishing pumps. In the past, anchovy kilka amounted to 80-90 percent of total kilka catch in Caspian Sea.

Anchovy kilka forms dense population in the depth of 30 m in the middle and southern Caspian Sea. In Winter, anchovy kilka live in southern part of the Caspian Sea, in Spring it migrates to middle Caspian. Feeding period in Summer often takes place in the middle and southern Caspian [2]. Anchovy kilka spawns at depths of 50-200 m in southern part of Caspian Sea [17, 18, 19].

Previous studies on population characteristics of anchovy kilka in Caspian Sea's Iranian waters were limited to studies in distribution [2] and stock assessment [1, 3, 4]. However, quantitative assessments are necessary for management and effective exploitation of the existing stock [13]. Despite of its economic and ecologic importance as a main commercial and food species in the Caspian Sea, there are no sufficient data on sex, growth and mortality of kilka in the southeast part of the Caspian Sea (territory of Mazandaran province). However, such data are especially important related to ecological changes occurred in the Caspian Sea. Moreover, invader species ctenophore Mnemiopsis leidyi which appeared in 1999 [5] have affected all components of the ecosystem used by kilka. Also, one of the purposes of catch and biology study is recognition of human and natural factors affecting fish population [14]. Thus, the aim of the present study is filling in the information gap of anchovy kilka population biology, catch assessment and creating a base for effective and optimal management of anchovy kilka catch in Mazandaran zone.

Material and Methods. During the sampling period (January-December 2008) 60 kg of kilka fishes have been used, 2770 fishes were allocated to biometry study, from which 338 were anchovy kilka. The samples were provided from landing in Babolsar harbor in Mazandaran province. The samples for this study were caught at depths of 40-100 m by conical lift nets equipped with underwater electric lights.

The samples were transported to the laboratory for conducting measurements. The samples were initially sorted into size bins. Then, the total weight (to the nearest 0.1 g), sex and maturity stages of ovary were determined. Sexual maturity classification was carried out based on six macroscopic stages in ovarian development (stage II is not ripe; stage III is almost ripe; stage IV is ripe; stage V is ripe and running and stage VI is spent) as defined by Biswas [6].

<u>Age determination method.</u> Age determination of anchovy kilka has been done with use of otoliths. Otoliths were provided at each biometry stage and of each length classes (144 specimen including both females and males). Otoliths were put in special plate containing glycerin. Age determination was done using stereomicroscope with light glinted from top with background being black [7].

<u>Data analysis method</u>. The length-weight relationship was calculated as following by statistical package in SPSS 11:

$$W = aL$$

where W is the fish weight (g), L - fork length (mm), a and b are the parameters [8].

Van Bertalanfi growth parameters were estimated using a non-linear estimation method [9] with use of software FISAT:

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

where t is age, Lt - fish length at t age, t_0 - age virtual assay in length of 0, L ∞ - computed possibly maximal length for this species, k - growth coefficient.

Survival rate (S) was calculated using the catch curve method [10]. The instantaneous coefficient of total mortality (Z) was transformed from the survival rate as $Z=-\ln S$.

Natural mortality coefficient (M) was estimated from tentative Pauly formula [11]:

$$\log(M) = -0.0066 - 0.279 \log(L_{\infty}) + 0.6543 \log(K) + 0.4634 \log(T)$$

where T is the water annual average temperature of fish habitat. In this study, T was 12⁰C. Fishing mortality coefficient (F) was calculated using the following formula:

Z = M + FExploitation rate (E) was calculated by [12]:

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

For determination of reproduction time, gonadosomatic index (GSI) was used [8]:

$$GSI = \frac{W}{W} \times 100$$

where w is gonad weight (g) and W is body weight (g).

Results and discussion.

Catch composition of three kilka species

All three kilka fishes (common, anchovy and bigeye) are present in catches. The most abundant in the catches are common kilka (88.06 percent) and the least - bigeye kilka (4.13 percent). Anchovy kilka abundance amounted to 7.81 percent. The most abundance occured in February (up to 27.2 percent) and the least - in June (up to 5.5 percent).

Catch, effort and CPUE for anchovy kilka

Aug

Sep

Oct

Nov Dec

total

Total catch of anchovy kilka in 2008 was 954 tons (Table 1).

160.7

69.8

24.8

138.5

121.6

9539

or Caspian Sea in 2008								
Month	Catch	Effort	CPUE					
Jan	22.8	327	0.07					
Feb	259.1	681	0.381					
Mar	51.7	417	0.124					
Apr	8.1	125	0.065					
May*	0	0	0					
Jun	5.3	51	0.104					
Jul	91.5	643	0.142					

828

453

218

523

779

5045

0.194

0.154

0.114

0.265

0.156

0.19

 Table 1. Catch, effort and CPUE of anchovy kilka in southeast part of Caspian Sea in 2008

The highest catch was observed in February (up to 259.1 tones) and the lowest - in June (up to 5.3 tones).

The highest fishing effort was in August (828 vessels per night) and the lowest effort was in June (51 vessels per night).

Maximum Catch Per Unit of Effort (CPUE) amount for anchovy kilka was in February up to 0.381 tons per vessel per night and its minimum was in April up to 0.065 tons per vessel per night.

Average length and weight for anchovy kilka

The study of the year 2008 shows that in the harvested fish, females have a more extended length range but there is no significant difference about the weight. Fork length average of anchovy kilka (male and female) was 116.4 ± 13 mm. About 46 percent of length abundance has belonged to 115-125 mm length classes. Average weight of anchovy kilka was 11.4 ± 3 g, about 67 percent of weight abundance has belonged to 8.4-13.6 g weight classes (Fig 1).



Fig. 1. Monthly fork length and weight average of anchovy kilka in southeast part of Caspian Sea in 2008

Van Bertalanfi population growth parameters and equation for anchovy kilka Growth parameters ($L\infty$, k, t0) for anchovy kilka have been estimated according to length and age data (Fig 2).



Fig. 2. Van Bertalanffi growth curve of anchovy kilka in southeast part of Caspian Sea in 2008.

The growth equation used is as follows:

$$L_t = 151 .94 \left[1 - \exp^{-0.28 (t+1.12)} \right]$$

Relation between fork length and weight for anchovy kilka

The fork length and weight regression of anchovy kilka was $W = 0.000349 \text{FL}^{2.18}$

(R = 0.908). With considering that calculated b was 2.18 (b < 3), growth pattern of this fish is negative allometric (p < 0.05).

Sex ratio for anchovy kilka

The sex ratio of female:male was 1:0.5 for adult anchovy kilka (n = 338) where females were dominant (Table 2).

Month	Male	Female
Jan	26	74
Feb	28	72
Mar	22	78
Apr	32	78
May	35	75
Jun	29	61
Jul	35	65
Aug	42	58
Sep	56	44
Oct	53	47
Nov	44	56
Dec	22	78

 Table 2. Sex ratio (%%) of anchovy kilka in southeast part of Caspian Sea in 2008

It can be seen that males of anchovy kilka were dominant in September and October.

Spawning and GSI changes for anchovy kilka

Study of sexual maturity stages in various months showed that the abundance of 4 and 5 sexual maturity stages increased starting April and reached to its maximum level in October, November and December. Spawning has been completely done in January and February, relative share of immature fishes (on stages 2, 3) was above 60 percent (Fig. 3).



Fig. 3. Monthly abundance percent of sexual maturity stages of anchovy kilka in southeast part of Caspian Sea in 2008.

GSI amount of anchovy kilka begins to increase from May. The highest amount of GSI was in December. It decreases from January reaching the minimum in February which indicates end of spawning. Afterwards, GSI amount does not tangibly increase during early spring and gonads are in rest. In late Spring and Summer, GSI amount begins to increase (Fig. 4).



Fig. 4. Monthly GSI average of anchovy kilka in southeast part of Caspian Sea in 2008

Natural, fishing and total mortality coefficients, survival rate and exploitation rate for anchovy kilka

According to catch curve method, annual survival rate of anchovy kilka has been estimated up to $0,343_{yr^{-1}}$. Based on this survival rate, total mortality coefficient (Z) of anchovy kilka has been estimated up to $1,07_{yr^{-1}}$. Natural mortality coefficient of anchovy kilka, estimated by tentative Pauly (1999) method, was $0,633_{yr^{-1}}$. Fishing mortality coefficient for anchovy kilka was $0,437_{yr^{-1}}$. Therefore, the exploitation rate of anchovy kilka has been estimated up to 0.408.

Age structure for anchovy kilka

Anchovy kilka population consisted of 7 age groups. 4-year age group appropriates 40.97 percent of total abundance and forms a dominant population. Age average in females was 4.225 ± 0.735 and its minimum and maximum were 2 and 7, respectively (n=78). Age average in males was 3.872 ± 0.746 and its minimum and maximum were 1 and 7, respectively (n=66) (Fig. 5).



Fig 5. Age abundance percent of anchovy kilka in southeast part of Caspian Sea in 2008

Catch at age analysis for anchovy kilka

From January to December 2008, 4-year old fishes have the highest catch (up to 40.97 percent, 390.86 tons) followed by 5-year old fishes with catch amounting to 20.14 percent (192.12 tons) and 2-years-old catch amount was 13.19 percent (125.87 tons) and 3 and 6-year old ones (each of 11.11 percent and 106 tons) (Table 3).

Age	1	2	3	4	5	6	7	Total
Number	2	19	16	59	29	16	3	144
Abundance (percent)	1.39	13.19	11.11	40.97	20.14	11.11	2.08	100
Catch (ton)	13.25	125.87	106.00	390.86	192.12	106.00	19.87	954.0

Table 3. Catch at age of anchovy kilka in southeast part of Caspian Sea in 2008

Kilka catch in Mazandaran zone decreased from 28 thousands tons in 1999 to 7.8 thousands tons in 2003 and then increased and reached to 13.2 thousands tons in 2005 (adopted from Mazandaran fisheries administration statistics during 1999-2005). Anchovy kilka catch decreased during this period (1998-2008) from about 26 thousands tons to 954 tons and CPUE decreased from 3.736 tons (per vessel per night) to 0.19 tons.

Anchovy kilka age study shows that 3-year old fish constituted the largest age group during 1997 and 1999 but 2-year old fish have increased in 2000. Afterwards, 3-year old fish were dominant again in 2001-2003 and 4-year old fish have appropriated to the most catch in 2004 [4].

Fork length average of anchovy kilka in southeast Caspian in 1997 was 95.2 mm. Then, it gradually decreased during 1998, 1999 and 2000 and reached to 87.8 mm but increased again after 2001 [4] reaching to 116.4 mm in 2008.

Weight average of anchovy kilka in 1997 was 6.1 gr gradually decreasing during 1998, 1999 and 2000 and reaching 4.4 gr, but increasing after 2001 [4] and reaching 11.4 gr in 2008.

Exploitation rate of anchovy kilka in this study (catch per fish stock) has been estimated up to 0.41. Also, their catch amount decreased by 2008 and as a result their age in catch increased.

Based on these data, it might be concluded that anchovy kilka stock decreased during 1997-2000 mainly due to over-fishing. This was accompanied with juvenilization of the population, reflected in reduction of average length and weight of population. Further increase of stock followed by increase of average length and weight and age of the fish was a result of regulated fishery and application of nature protection measures in Southern Caspian areas by Iranian government. Decrease of the fishing pressure is also reflected in decrease of share of fishing mortality and consequently in increase of the share of natural mortality in the total mortality by 2008.

Investigation in 1997-2004 shows that male were dominant in the catches, whereas change of female:male ratio towards increase of females was observed for 2008. This also confirms existence of relatively improved habitat conditions. Observed peak of males during September-October 2008 can be attributed to seasonal variation of responses to light disturbance by different sexes. Ben-Yami [15] reported that there were different responding behaviors of fish to light. A key hypothesis is that fish are attracted to light for feeding. It is well-known that artificial light attracts many aquatic organisms [16] and perhaps the motivation for attraction is related to increased prey density within the lighted area. With development of gonads, females appear to be less attracted to light. As they approach spawning time, they cease feeding and disappear from the catches. In the case of males, they continue feeding during spawning period and it seems that their response to light disturbance remains unchanged [15].

It should also be noted that these changes coincided with ecological changes caused by invasion of ctenophore species. Negative allometric growth of anchovy kilka observed for 2008 shows that the fish feeds insufficiently, which might be a result of the effect caused by the invader. Besides, global climatic changes such as Caspian Sea level

change might affect the numbers of anchovy kilka due to changes of conditions of natural reproduction. Also, anchovy kilka is affected by predators such as seal, sturgeon, etc. Thus, alongside with the main factor – fishery, there still exist other environmental factors influencing anchovy kilka population and cumulative effect of all factors may lead to stock depletion.

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