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**Suleymanov S Sh**  
Institute of Zoology, National  
Academy of Sciences of  
Azerbaijan, Passage 1128, block  
504, Baku, AZ1073, Azerbaijan

**Azizov AP**  
Institute of Zoology, National  
Academy of Sciences of  
Azerbaijan, Passage 1128, block  
504, Baku, AZ1073, Azerbaijan

**Seyid-Rzayev MM**  
Institute of Zoology, National  
Academy of Sciences of  
Azerbaijan, Passage 1128, block  
504, Baku, AZ1073, Azerbaijan

**Correspondence**  
**Suleymanov S Sh**  
Institute of Zoology, National  
Academy of Sciences of  
Azerbaijan, Passage 1128, block  
504, Baku, AZ1073, Azerbaijan

## To the issue of forecasting of spawning migrations of herrings (*Alosa*) near in the western coast of the Caspian Sea

**Suleymanov S Sh, Azizov AP and Seyid-Rzayev MM**

### Abstract

On material based on trawling shootings and the netting catches carried out near the western coast of Caspian Sea in 2014 - 2015, and also according to commercial statistics, the periods of spawning migrations of herrings (*Alosa*) are analyzed. Features of behavior of herrings inhabiting the western shelf of Caspian Sea, including periods, ways and the reasons of their migrations from southern to the northern Caspian are studied. It is shown that environmental factors can influence to some extent the time of the beginning of spawning migration what that might be related to processes of evolution of these species which are shaped by natural selection. It is without doubt that the origin and development of migratory ways are also connected with the geological past of the basin. Dependence of spring migration of herrings from horizontal and vertical migrations of plankton prey is established. For the first time we established connection of external factors of the environment with internal factors and their interactions. Spawning migrations depend not only on external factors, but also on the sexual hormones which actively influence development of gonads.

**Keywords:** Herrings, spawning migration, stage of maturity, maturity coefficient, fatness, feeding

### 1. Introduction

Opuntia Herrings (*Alosa*) are the most numerous commercial fishes in the Caspian Sea. The range of these species encompasses almost all areas of the Caspian Sea, except for Kara Bogaz Gol gulf [6, 7, 14]. Migrations of Caspian herrings developed in parallel with their evolution throughout long process of formation of the Caspian Sea [11, 16]. Migrations are result of the adaptation of different species of herrings to various environmental conditions of the Caspian Sea which were developed in the course of evolution of these fishes. The periods of migration of fishes in the Caspian Sea are poorly studied. Most researchers of Caspian herrings considered the water temperature as a major factor affecting the time of beginning of spring spawning migration and approaches of fishes to the coast [2, 4]. N. A. Dmitriyev [5] conducted observations of approaches of herrings to the coast and have found that water temperature during approaches of shads to the coast is not constant in different years what is an argument against prevailing influence of only one this factor.

Unfortunately, most researchers [2, 4, 5, 10] did not establish relation between external factors of the environment and internal state of fishes and their interaction. They had no enough data on biology of herrings and considered approaches to the coast to be related only to water temperature.

Due to the changed ecological conditions, and also reorganization of coastal catches of herrings near the western coast of Caspian Sea, the problem of forecasting of spawning migrations of herrings in narrow strips in foreshore, i.e. in the places covered by seine catching or stationary nets, is of great importance.

### 2. Materials and methods

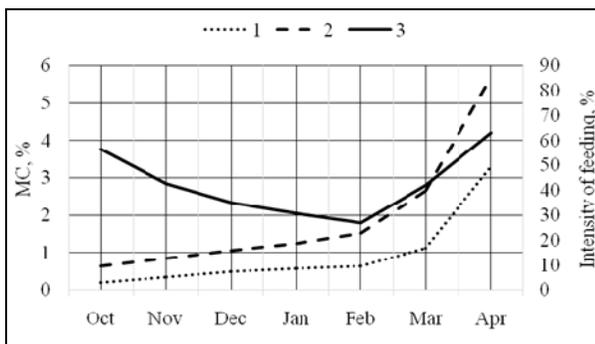
The material was collected in the Azerbaijan sector of the central and southern Caspian Sea in 2014 – 2015 (Fig.1). The catches in the open sea were carried out by a seabed trawling (24.7 m), and in a coastal zone with stationary nets 25 m long, with mesh size from 28 to 70 mm.



**Table 1:** Seasonal changes of maturity coefficient of dolgin herring and Caspian shad 2014 - 2015.

Month	Sex	Dolgin herring			Caspian shad		
		I decade	II decade	III decade	I decade	II decade	III decade
October	♂	0.13	0.19	0.27	0.22	0.25	0.29
	♀	0.56	0.63	0.69	0.79	0.89	1.01
November	♂	0.31	0.35	0.40	0.34	0.36	0.41
	♀	0.78	0.83	0.90	1.10	1.18	1.22
December	♂	0.47	0.51	0.53	0.46	0.48	0.53
	♀	1.01	1.05	1.11	1.25	1.28	1.32
January	♂	0.55	0.56	0.59	0.55	0.58	0.60
	♀	1.18	1.25	1.33	1.37	1.48	1.57
February	♂	0.62	0.63	0.66	0.63	0.70	0.84
	♀	1.43	1.52	1.60	1.67	1.85	2.02
March	♂	1.00	1.10	1.30	1.13	1.65	2.36
	♀	2.23	2.65	3.10	2.22	2.77	3.52
April	♂	2.11	2.77	3.79	3.94	4.81	4.95
	♀	4.25	5.24	6.57	5.22	5.73	6.45

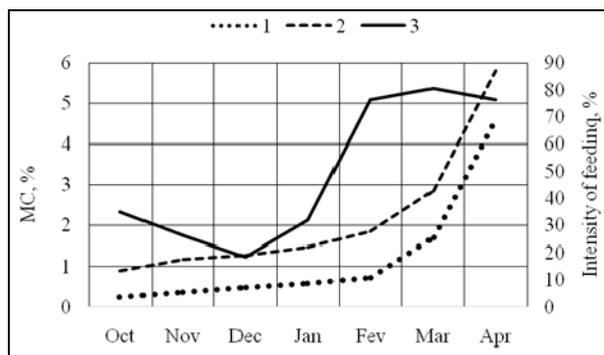
Approach of dolgin herring from overwintering places to the coast begins from that moment when they proceed from a winter state to the following stage – active preparation to migration. From this time dolgin herring starts to feed intensively, following its main prey – kilkas *Clupeonella cultriventris caspia* and *C. engrauliformis* which during this period come from open parts of the sea closer to the coast. In 2014 - 2015 the beginning of fast development of gonads in dolgin herring coincided with the beginning of its approach to a coastal zone. But the main part of population of dolgin herring in 2015 was biologically prepared to migration in the third decade of March. Since that time its mass spawning migration to the northern Caspian Sea began.



**Fig 2:** The coefficient of maturity and intensity of feeding of dolgin herring: 1-The coefficient of maturity in males; 2- The coefficient of maturity in females; 3-The intensity of feeding.

Development of gonads in Caspian shad from October to February also proceeds slowly (Fig 3). The maturity coefficient in males in October makes up 0.22%, and increases to 0.84% by March. Females over the same period give a few high rates. So, in October their coefficient of a maturity was 0.79%, and increased to 2.02% by March (Table 1). Intensity of feeding of shads during the autumn and winter periods is weak. From third decade of February individuals of shads become more active. Intensity of feeding increases. Empty stomachs in February made up 23.0%. In March, during the before migration period feeding reaches the maximum intensity (Fig 3). The same phenomenon takes place with fatness. From October to December fatness increases (Fig 4). In January and February it decreases and in March reaches a maximum – 1.40. From the time of mass spawning migration all biological indicators, intensity of feeding and fatness decrease decreases. The fastest development of gonads in shads begins from the second

decade of March. At the end of March the third stage of development of gonads completes and then there is a fast transition to III-IV and IV stages. In males the mass of testicles increased within the first decade of April in comparison with the end of March by 2 times whereas in females the mass of ovaries increased during this period by 2, 3 2-3 times.



**Fig 3:** The coefficient of maturity and intensity of feeding of Caspian shad: 1-The coefficient of maturity in males; 2- The coefficient of maturity in females; 3-The intensity of feeding

Actively operating sexual hormones at maturity stage of sexual products of III and older induce shads to make spawning migration. In 2015 we observed a mass spawning pass in the first decade of April.

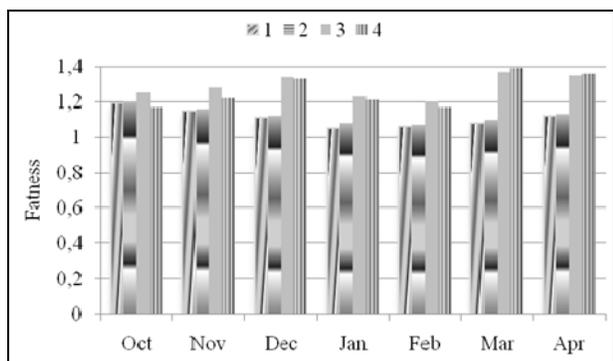
It is revealed that in 2015 development of gonads in herrings was faster in comparison with 2014, and as a result their spawning migration began earlier than in 2014.

In dolgin herring gonads of males in the third decade of March 2014 constituted 1.26%, and in females – 2.77%, while in 2015 they constituted 1.37% in males and 3.58% in females. Given that rate of development of gonads in males in March 2015 made up from 0.10 to 0.17% per decade, and in females from 0.43 to 0.76%, and suggesting that in 2014 gonads in dolgin herring developed with similar rate one can conclude that generation of 2014 lag

**Table 2:** Some biological indicators of herrings in the Caspian Sea in 2014 - 2015.

Month	n	SM					MC		Fatness		Stomach filling %				
		II	II-III	III	III-IV	IV	♂	♀	♂	♀	0	1	2	3	4
Dolgin herring															
Autumn X-XII	110	100	-	-	-	-	0.35	0.84	1.14	1.15	60.9	15.5	11.8	9.1	2.7
January	85	100	-	-	-	-	0.57	1.25	1.07	1.09	69.5	8.4	9.5	5.4	7.2
February	42	64.7	35.7	-	-	-	0.64	1.52	1.06	1.07	71.4	2.4	11.9	9.5	4.8
March	90	25.5	37.8	30.0	6.7	-	1.13	2.66	1.07	1.10	57.8	3.3	20.0	11.1	7.8
April	51	5.9	29.4	49.0	15.7	-	1.94	3.70	1.12	1.13	49.0	2.0	15.7	19.6	13.7
April (coast)	62	4.8	9.7	19.4	40.3	25.8	3.30	5.70	-	-	37.1	1.6	38.7	16.1	6.5
Caspian shad															
Autumn X-XII	116	100	-	-	-	-	0.39	1.11	1.29	1.24	69.8	25.0	2.6	1.7	0.9
January	77	100	-	-	-	-	0.60	1.50	1.23	1.21	67.5	13.0	9.1	6.5	3.9
February	61	72.1	27.9	-	-	-	0.77	1.92	1.20	1.17	23.0	29.5	34.4	8.2	4.9
March	165	6.1	52.7	41.2			1.92	3.25	1.39	1.40	19.4	20.6	12.7	25.5	21.8
April	123	-	-	33.3	66.7	-	3.58	4.10	1.35	1.36	23.6	13.0	20.3	16.3	26.8
April (coast)	138	-	-	19.6	37.7	42.7	4.70	6.25	-	-	82.6	2.9	11.6	2.9	-

Behind in development by 15–20 days in as compared to 2015. These data coincide with respective times of approach of herrings to the coast in the spring. The spawning pass of dolgin herring in 2015 began in the in the first decade of March second five-day of March whereas in 2014 it occurred since the beginning of April, i.e. 20 days later.



**Fig 4:** The fatness of dolgin herring and Caspian shad: 1-males of dolgin herring; 2-females of dolgin herring; 3- males of Caspian shad; 4- females of Caspian shad.

Development of gonads in Caspian shads in March, 2014 - 2015 is same, it is apparently explained by more or less similar overwintering conditions. Both in 2014 and 2015, the bulk of Caspian shads spend winter period in western part of southern Caspian Sea. Temperature conditions of overwintering areas in these years were approximately similar. The food supply in 2014 - 2015 in the southern Caspian Sea was subject to weak fluctuations by Suleymanov *et al.* [15]. Therefore the rate of biological preparation to spawning in shad proceeded in these years more or less equally. Only from the first decade of April 2015 we observed significantly amplified development of gonads in comparison with 2014. From this time the spawning migration began. In 2014 intensive development of

gonads began since the second decade of April. Therefore the spawning migration of shads started slightly later.

**4. Discussion**

Not all individuals prepare to for migration at the same time. The herrings occurring in areas with most favorable ecological conditions mature faster and migrate earlier in comparison with those which live in areas with worse conditions. Such unevenness in development and maturing results in prolixity of spawning pass of herrings. The fast maturing individuals migrate earlier, while those that unprepared to migration choose prey rich areas where they feed until reaching maturity.

The adaptation of herrings to various conditions of the environment and to different spawning areas provides an opportunity to them to use most economically and expediently a basin and its food resources. Therefore, to predict spring migration of different species of herrings, except for knowledge of environmental conditions under which their development and migration take place, we also need to know biological state of herrings during various periods of their life.

In Table 3 some biological indicators of readiness of herrings to spawning migration are given. Here we distinguish distinguished four stages of biological state of herrings. Each stage is characterized by a certain fatness and development of gonads. Moreover, it is also necessary to consider intensity of feeding, degree of concentration of fishes and interspecies isolation.

When carrying out investigation of herrings in the sea, these main biological indicators will allow to evaluate degree of readiness to migration of different species of herrings and to give short-term forecasts about time of migration of fishes.

There is no need to give the characteristics of each stage of biological state of herrings, as it is clearly seen from Table 3, Moreover, we discussed these above.

**Table 3:** Some biological indicators of readiness of herrings to spawning migration in 2014 – 2015.

Stage of biological state of herrings	Dolgin herring				Caspian shad			
	Fatness	MC		Period of observation	Fatness	MC		Period of observation
		♂	♀			♂	♀	
Winter stage of herrings	1.07	0.70	1.73	End of February	1.27	1.08	1.92	End of February
Beginning of spring movement of herrings from overwintering areas to coastal zone	1.05	0.96	2.10	Beginning of March	1.30	1.15	2.26	Beginning of March
Stage of preparation to migration	1.12	1.0 – 1.2	2.4 – 3.0	Second half of March	1.38	2.1 – 3.2	3.3 – 3.5	End of March
Beginning of mass migration	1.10	1.4 – 2.1	2.9 – 4.0	End of March – beginning of April	1.35	3.5 – 4.4	3.6 – 5.0	First half of April

It is only necessary to consider two last stages which are of most importance important for forecasting. Herrings which are at stage of preparation to migration are characterized by well-developed sexual products (III stage of maturity in Caspian shads and II-III in dolgin herring) and high fatness. During this period herrings feed intensively, being in the discharged state. Migratory herrings (Caspian shad, etc.) has more developed gonads – stages of III-IV and IV, in dolgin herring - III and older, the fatness is also high, but intensity of feeding is reduced. Empty stomachs in dolgin herring at the end of March made up 57.8%, and in Caspian shads in the middle of April up to 82.6%. Interspecies and intraspecies isolations are observed Interspecific and intraspecific isolations were observed. Density of herrings increases. Increased

Except short-term predictions of migration of fishes based on observations of their biological state and taking into account ecological factors, it is possible to make long-term predictions of beginning of spring migration (one – two months earlier before beginning), using for this purpose comparative data on rate of development of gonads for last years, and also for this year.

Biology of Caspian herrings are still much insufficient. Some questions require special investigation. However, the biological state of herrings indifferent periods of their life activity taking into account ecological factors that allow to provide fisheries with more correct and scientifically based forecasts about time of beginning of spring migration of herrings.

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