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Feeding of the Caspian shad *Alosa caspia* (Eichwald, 1838) in the western part of the Caspian Sea

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Seasonal changes in feeding of Caspian shad *Alosa caspia* (Eichw.) inhabiting western part of Caspian Sea were studied. Quantitative and qualitative features of its food spectrum, depending on different seasons of the year are given. It is established, that throughout the year the main food of this species is presented by Copepoda and Mysidacea, while other groups of crustaceans are represented insignificantly. Importance of certain species of copepods and misids in food of fishes is influenced by their ecological, morphological and functional peculiarities. Food spectrum of *Alosa caspia* is related to its life cycle and migration of zooplankton. Caspian shad feeds most intensively in spring before spawning (March – April) and in the middle summer (July) after spawning. Compared to other seasons of the year in the summer time Caspian shad expanded its range that encompassed the whole western part of Caspian Sea.

Key words: *feeding, caspian shad, copepods, misids, index of stomach filling, fatness.*

Питание каспийского пузанка *Alosa caspia* (Eichwald, 1838) в западной части Каспия

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Рассмотрено сезонное изменение питания каспийского пузанка *Alosa caspia* (Eichw.), обитающего в западной части Каспийского моря. Дана качественная и количественная характеристика его пищевого спектра в зависимости от сезонов года. Выявлено, что основу питания в течение всего года составляли копеподы и мизиды, другие группы ракообразных представлены незначительно. Значение отдельных видов копепод и мизид в пище рыб обусловлено их экологическими и морфофункциональными особенностями. Сезонные изменения видового состава и соотношения кормовых объектов в пище обусловлены жизненными циклами рыб и миграциями организмов зоопланктона. Каспийский пузанок наиболее интенсивно питается весной, до нереста (март – апрель), и в середине лета (июль), после нереста. По сравнению с другими сезонами года, в летний период ареал нагула пузанка расширяется и охватывает всю западную часть Среднего Каспия.

Ключевые слова: *питание, каспийский пузанок, копеподы, мизиды, индекс наполнения, упитанность.*

Introduction

The Caspian shad *Alosa caspia* (Eichw.) is an important commercial fish for costal fisheries by shore seines and nets in western part of Caspian Sea (Kushnarenko, 1984; Suleymanov, Seid-Rzayev, 2012). Some peculiarities of biology of the Caspian shad inhabiting western part of Caspian Sea are poorly studied. The questions concerning feeding of this planktonophagous fish have been addressed only in a few publications in the past century (Derzhavin, 1918; Chayanova, 1940). Changes of hydrological and hydrochemical regimes of the Caspian Sea during the last decades (Mirzoyev, 2011) as well as migration of new hydrobionts to the Caspian basin (e.g. *Mnemiopsis leidyi* and others) and intensification of kilka *Clupeonella engrauliformis* trade certainly affected the feeding of shads. In present work we consider the features and intensity of feeding of Caspian shad in the western part of Caspian Sea. Moreover, the special attention has been paid to the study of feeding of Caspian shad when it approaches area of seine netting in the western part of Caspian Sea. The obtained results will help to reveal more correct, scientifically based methods to search for commercial aggregations of Caspian shad in different seasons of the year in different parts of Caspian Sea.

Material and methods

The investigation was conducted in the western part of Middle and South of the Caspian Sea in 2011–2012 (Fig. 1). Fishes were captured in narrow coastal zone by stationary nets (28–30; 40–50; 60–70 mm), and in open areas of Caspian Sea at the depth 10–100 m during complex trawling (24,7 m) sturgeon shootings on NSS "Alif Gadzhiev".

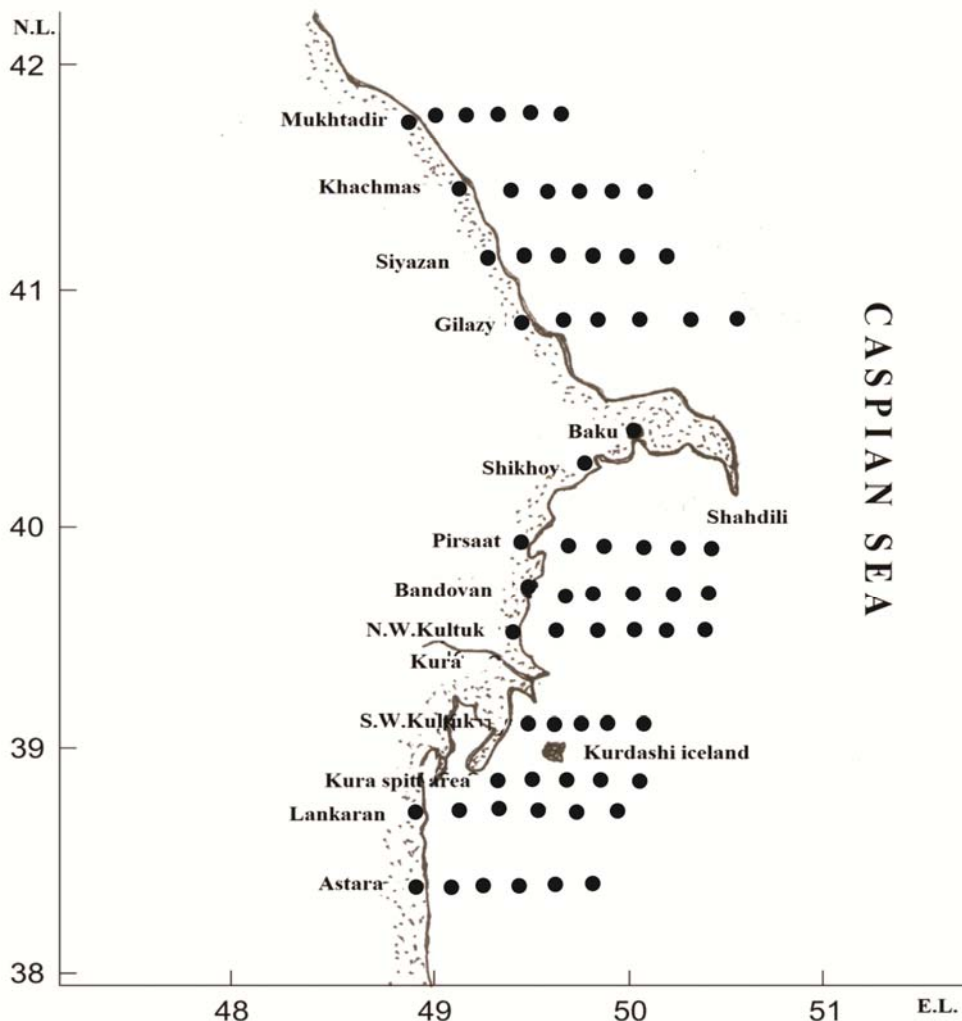


Fig. 1. Schematic map of the stations of the study area

All biological analyses were carried out by the standard methods (Pravdin, 1966). Tests on food of fishes were processed according to standard quantitative and measuring methods (Methodical textbook ..., 1974).

Stomach contents were sorted and prey items were identified to the lowest possible taxonomical level. Proportion of weight of each prey group of total mass of food was calculated (W %). The general index of stomachs filling (GIF, ‰) and proportion of fishes with empty stomach (%) were calculated. In total 345 specimens of fishes ranging from 15.3 to 24.5 cm were observed, 279 of which were without food. To describe the seasonal dynamics of feeding the following periods were depicted: spring (March – April), summer (July – August), and winter (January – February).

Results and discussion

Throughout the year the Caspian shad *Alosa caspia* (Eichw.) occurs in all three parts of Caspian Sea (Kazanchev, 1981; Suleymanov et al., 2012). During spawning period it occurs in the Northern Caspian Sea then migrates to Central Caspian Sea and overwinters in the Southern Caspian Sea.

In the southwest of Caspian Sea Caspian shad feeds almost all the year round. Dynamics of feeding of Caspian shad during the year is expressed in changes of intensity of feeding and seasonal changes in

food spectrum. It is connected not only with water temperature, but also with habitat and densities of prey populations.

Depending on the season of year Caspian shad inhabits different depths. It has been established that in the winter season Caspian shad is mainly distributed (61.7–66.3 %) in areas near Lenkoran, Kura braid and Kura stone at 35–50 meter depths, with water temperature 7.6–9.1°C (Kuliev, Suleymanov, 2005, 2010). These areas are characterized by greatest biomass of plankton and constant hydrochemical conditions (temperature, current). After summer feeding, individuals of this species reach the greatest fatness in December (1.34–1.46) that allows them to spend winter without intensive feeding.

In February 2011 in the region of Lenkoran stomach contents of 32 Caspian shads were investigated. The main food of Caspian shad (17.9–23.6 cm long) constituted Copepoda, including *Calanipeda aquae dulcis* (33.2%), *Acartia clausi* (17.3%), *Halicyclops sarsi* (8.5%) and *Heterocope caspia* (7.5%). The proportion of misids (*Paramysis kessleri*, *P. eurylepis*, *P. grimmii*) in diet of this size group did not exceed 13.4% of weight of contents of stomachs. The third and fourth most important prey groups were Cumacea (*Pterocuma pectinata*, *P. rostrata*, *Stenocuma graciloides*) – 7.0% and Amphipoda (*Niphargoides robustoides*, *N. sarsi*) – 5.0%. The mean index of stomach filling equaled 53.5 ‰ (table 1). During this period more than 62% of fishes were found with food, and feeding indexes in most cases decreased with age of fishes.

Near the Kura braid the main food of Caspian shad (15.3–22.6 cm long) were Copepoda (57.2%) and Mysidacea (21.5%). Besides, considerable number of prey items consisted of Cumacea and Amphipoda which constituted respectively 8.6 and 4.2%. The winter period was characterized by low index of filling (44.6 ‰) and a high proportion of individuals with empty stomach (43.8%).

Approximately the same distribution of Caspian shad was observed in the winter 2012, but density of aggregation of fishes was slightly increased that is apparently due to reduction of overwintering area. During this period in Lenkoran and Kura braid parts stomach filling index of Caspian shad was low (29.3–41.2 ‰). Considerable percent of individuals with empty stomach (38.5–26.3 %) indicates weak feeding of Caspian shad. The main object of food in all areas investigated by us was Copepoda, constituting from 46.5 to 71.3% of the total weight of food (table 2). Secondary food items were Cumacea (from 11.9 to 26.0%) and Mysidacea (from 5.7 to 20.0%). In the Lenkoran region Amphipoda (4.2%) also had some importance.

In the spring season Caspian shad migrates in the outfall of the river Kura to depths of 10–15 meter, rising to the water surface for feeding and spawning, then migrates to the region near Chilova Island, and also to the border between Southern and Central Caspian Sea. Water temperature in a coastal zone increases at this time to 10–12°C. Spring approaches of Caspian shad to coastal zone coincide with zooplankton migration to western shores of Caspian Sea. Similar dependence is also observed in the rest time of the year (Suleymanov, Seid-Rzayev, 2012). In the first half of March 2011 the intensity of feeding of Caspian shad in Kura braid and Shikhov parts was the same, as in previous months, but in the second half of March, when individuals of this species started to migrate to the North, their feeding intensity sharply increased. The mean index of filling of stomach in individuals near Kura braid equaled 67.5 ‰, near Shikhov – 90.2 ‰. Proportion of shads with empty stomach near Kura braid made up 11.1%, while near Shikhov part they missed absolutely. At this time the main food item of Caspian shad (16.6–24.0 cm long) at the study areas was Copepoda (*Acartia clausi*, *Heterocope caspia*, *Nauplii Copepoda* etc.), composing from 78.4 to 86.3% of total mass of the food. Mysidacea was second abundant prey type represented in moderate proportions – 5.5–14.5%, other prey groups were found in the diet of shads in low percentage (table 1).

Food spectrum of Caspian shad, captured by stationary nets in coastal zone in the spring season of 2011 in the Central part of Caspian Sea (in Hudat region) is very different, the main prey are constituted by organisms (plankton-benthic crayfishes), living in a coastal zone at a depth from 0 to 25 m. Here especially abundant prey groups are Cumacea, constituting 39.3% of total food mass; Mysidacea and Amphipoda collectively made up 21.2%. The percentage of Copepoda reached 34.1%, of which most abundant was *Acartia clausi* (19.5 %) followed by Nauplii of copepods (8.2%) while the proportion of *Calanipeda aquae dulcis* was very insignificant – 1.9% (table 1). Percentage of feeding fishes in the spring in Khudat region constituted 93.3%, and the mean index of stomach filling is 102 ‰.

At the beginning of April 2012 in coastal zones near Shikhov and Pirallakhi the proportions of individuals without food constituted 6.5 and 9.4% respectively. Such a high activity in food consumption is caused by maturing of sexual glands which in April reach the III–IV and IV stages of maturity. At this time main part of the diet of Caspian shad (17.0–23.8 cm long) near Shikhov composed Copepoda (37.6%), Mysidacea (30.0%) and Cumacea (20.9%) (table 2). The same prey groups were also most important in food

spectrum of Caspian shad near Pirallakhi – Copepoda (40.4%), Mysidacea (34.2%) and Cumacea (13.5%). Mean indexes of stomach filling were 105‰ near Shikhov and 127.3‰ near Pirallakhi (table 2).

Table 1.
Prey composition of Caspian shad *Alosa caspia* in the western part of Caspian Sea in 2011
(expressed as % of total food mass)

Prey composition	Winter		Spring			Summer	
	Lenkoran part	Kura braid part	Kura braid part	Shikhov part	Khudat part	Mukhtadyr part	Khachmas part
Cladocera	1,5	0,9	0,5	0,3	-	-	1,2
<i>Pleopis polyphemoides</i>	1,2	0,9	0,2	-	-	-	0,2
<i>Cercopagis longiventris</i>	0,3	-	0,3	0,3	-	-	1,0
Copepoda	66,5	57,2	78,4	86,3	34,1	74,5	60,0
<i>Acartia clausi</i>	17,3	11,1	49,9	24,2	19,5	3,7	6,0
<i>Halicyclops sarsi</i>	8,5	19,3	0,3	2,0	2,5	11,9	8,0
<i>Calanipeda aquae dulcis</i>	33,2	24,9	3,7	8,0	1,9	52,4	43,6
<i>Heterocope caspia</i>	7,5	0,5	14,2	36,6	2,0	6,5	2,4
<i>Naupli Copepoda</i>	-	1,4	10,3	15,5	8,2	-	-
Mysidacea	13,4	21,5	14,5	5,5	11,6	15,1	19,7
<i>Paramysis kessleri</i>	6,5	7,3	3,6	-	6,4	4,4	7,5
<i>P. baeri</i>	-	0,7	4,7	1,0	0,3	-	-
<i>P. eurylepis</i>	4,7	9,5	4,0	-	3,4	8,2	5,7
<i>P. grimmi</i>	2,2	4,0	0,5	3,3	-	2,5	6,5
<i>P. lacustris</i>	-	-	1,7	1,2	1,5	-	-
Cumacea	7,0	8,6	2,0	1,5	39,3	1,8	4,3
<i>Pterocuma rostrata</i>	2,0	1,2	-	-	2,7	-	0,4
<i>P. pectinata</i>	4,3	3,9	1,6	0,7	16,8	1,0	-
<i>Stenocuma diastylodes</i>	-	2,0	0,4	-	5,6	-	1,7
<i>S. tenuicauda</i>	-	1,0	-	0,6	2,7	-	1,8
<i>S. graciloides</i>	0,7	0,5	-	0,2	11,5	0,8	0,4
Amphipoda	5,0	4,2	3,5	3,1	9,6	6,2	8,7
<i>Dikerogammarus haemobaphes</i>	-	1,3	0,7	-	5,3	4,3	3,6
<i>Niphargoides robustoides</i>	3,1	0,5	-	2,6	1,1	1,9	2,4
<i>N. sarsi</i>	1,9	0,7	-	0,5	2,0	-	1,5
<i>N. maeoticus</i>	-	1,7	2,8	-	1,2	-	1,2
Others	6,6	7,6	1,1	3,3	5,4	2,4	6,1
Number of stomachs	32	16	27	26	30	27	39
Percentage of empty stomachs	37,5	43,8	11,1	-	6,7	14,8	12,8
Index of stomach filling	53,5	44,6	67,5	90,2	102	137	109
Fatness coefficient (after Fulton)	1,30	1,24	1,26	1,29	1,33	1,23	1,27

After spawning (July), begins the period of most intensive feeding. Many researchers (Chayanova, 1940; Smirnov, 1950; Shorygin, 1952; Vetchanin, 1984), in particular A.N.Derzhavin (1918) consider the postspawning period as a time of the greatest consumption of food by this species. Using trawling catches it has been established that the highest densities of Caspian shad in July occur in Mukhtadir and Hachmas parts of Central Caspian Sea at depths of 35–50 m. Therefore, in the summer the deep-water area is also most prey rich region for Caspian shad.

In open areas of Caspian Sea during the all seasons Copepoda play most important role in feeding of Caspian shad. It well corresponds to life style of this fish which prefer to forage in open areas where

Copepoda have greatest biomass among plankton organisms. The following data about importance of various groups in food of Caspian shad demonstrate changes in character of its feeding throughout the year.

Table 2.
Prey composition of Caspian shad *Alosa caspica* in the western part of Caspian Sea in 2012
(expressed as % of total food mass)

Prey composition	Winter		Spring		Summer	
	Lenkoran part	Kura braid part	Shikhov part	Pirallakhi part	Khachmas part	Kilyazi part
Cladocera	0,7	0,4	0,3	-	0,5	0,9
<i>Pleopis polyphemoides</i>	0,7	0,4	-	-	-	-
<i>Cercopagis longiventris</i>	-	-	0,3	-	0,5	0,9
Copepoda	71,3	46,5	37,6	40,4	82,5	58,2
<i>Acartia clausi</i>	10,3	16,5	21,5	13,5	20,9	12,1
<i>Halicyclops sarsi</i>	-	-	6,5	3,7	4,4	2,9
<i>Calanipeda aquae dulcis</i>	40,5	20,0	3,0	7,9	50,0	33,3
<i>Hetercope caspia</i>	20,2	9,5	2,6	11,5	6,3	8,4
<i>Naupli Copepoda</i>	0,3	0,5	4,0	3,8	0,9	1,5
Mysidacea	5,7	20,0	30,0	34,2	7,3	19,4
<i>Paramysis kessleri</i>	2,5	11,3	15,4	9,9	2,5	8,7
<i>P. baeri</i>	-	-	2,5	3,7	-	-
<i>P. eurylepis</i>	1,2	5,4	7,3	13,0	4,1	6,8
<i>P. grimmi</i>	1,7	3,3	3,1	4,8	0,7	3,9
<i>P.l acustris</i>	0,3	-	1,7	2,8	-	-
Cumacea	11,9	26,0	20,9	13,5	2,2	5,1
<i>Pterocuma rostrata</i>	0,5	-	0,2	1,2	-	1,3
<i>P. pectinata</i>	5,1	7,5	2,4	-	0,5	-
<i>Stenocuma diastylodes</i>	4,3	12,2	14,1	11,4	-	3,0
<i>S. tenuicauda</i>	0,3	2,4	-	0,9	1,4	0,8
<i>S. graciloides</i>	1,7	3,9	4,2	-	0,3	-
Amphipoda	4,2	2,6	7,3	5,9	3,7	6,6
<i>Dikerogammarus haemobaphes</i>	-	-	0,7	1,3	0,7	2,9
<i>Niphargoides robustoides</i>	1,3	0,3	2,6	3,6	2,0	1,3
<i>N. sarsi</i>	1,0	1,6	4,0	0,8	1,0	0,5
<i>N. maeoticus</i>	1,9	0,7	-	0,2	-	1,8
Others	6,2	4,5	3,9	6,0	3,8	9,8
Number of stomachs	13	19	31	32	23	30
Proportion of empty stomachs	38,5	26,3	6,5	9,4	8,7	16,6
Index of stomach filling	29,3	41,2	105	127,3	152	97,7
Fatness coefficient (after Fulton)	1,28	1,23	1,30	1,32	1,25	1,28

In the summer of 2011 in the area near Mukhtadir in the diet of Caspian shad (17,5–24,5 cm long) prevailed Copepoda, namely *Calanipeda aquae dulcis* (52,4%). The percentages of Amphipoda and Mysidacea were much lower – 15.1 and 6.2% respectively (table 1). In the food of Caspian shad in Khachmas part Copepoda was also by far dominant group (60.0%), followed by Mysidacea (19.7%) and Amphipoda (8,7%). Proportion of Cumacea and Cladocera was insignificant – 5.5%. Mean indexes of stomach filling equaled 137‰ near Mukhtadir and 109‰ near Khachmas (table 1).

In July 2012 contents of 48 stomachs of Caspian shad (16,8–24,2 cm long) occurring near Khachmas and Kilyazi were investigated. In all study areas Copepoda was by far much dominant food component of

Caspian shad (58.2–82.5 %). Mysidacea were presented in moderate proportions – 7.3–19.4%, while other prey groups were insignificant. At this time in Kilyazi part the number of individuals found with food decreased almost in all age groups, though indexes of stomach filling in certain specimens exceeded 297‰. Reduction of mean indexes of stomach filling (97.7‰) during the summer period is explained by the fact that at high water temperature the process of digestion of food in Caspian shad is much more accelerated. So the food does not accumulate in the stomach. During this period mean index of stomachs filling in individuals of Caspian shad inhabiting Khachmas part was 152‰.

Conclusion

The conducted investigation revealed that the main food groups of Caspian shad are Copepoda (61.1%), Mysidacea (16.8%) and Cumacea (11.1%). Prevalence of certain type of prey in the diet of Caspian shad in different seasons of year depends on relative abundance of potential prey in region occupied by species. Changes in feeding intensity of Caspian shad is closely connected with hydrological conditions (a current, temperature, etc.) and with their physiological state, first of all with development of sexual glands. One can conclude that densities of potential prey populations in south-western part of Caspian Sea can support populations of local species of fishes including Caspian shad. Taking into account that the main prey groups of Caspian shad such as Copepoda, Mysidacea and Cumacea are among the most abundant organism in Caspian Sea it could be considered as a good precondition for maintenance the density of population of this species at high level.

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