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Feeding of the caspian seal (*Pusa caspica* Gmelin, 1788) during haul out periods at the Kenderli rookery (Middle Caspian)

The Kendirli Haul-Out Site of the Caspian Seal served as the sole haul-out location in the Central Caspian Sea. Consequently, data obtained regarding the seal's diet at this site holds significant importance for the study and conservation of the Caspian Seal population. This study analyzed the diet of the Caspian Seal based on fecal collections from the Kendirli Haul-Out Site spanning from 2015 to 2019. Given the Caspian Seal's endangered status, a vital in vivo method of coprological analysis was employed to assess its diet. Comparative analysis of the seal's diet was conducted across seasons and years, and fish lengths consumed by seals were determined using otoliths extracted from feces. The study revealed that the Caspian Seal's diet at the Kendirli Haul-Out Site comprises 11 fish species, including species of the Cyprinidae family and Benthophilus genus, along with unidentified species of gobies. It was observed that the seal's diet varies seasonally; during autumn, the primary food source consists of gobies, whereas in spring, *Atherina caspia* predominates the diet. Additionally, carp species, *Clupeonella caspia*, and *Alosa braschnikowi* are present in the spring diet but absent in the autumn diet. Reconstruction of fish length ranges for three fish species — *Neogobius melanostomus affinis*, *N. pallasi*, and *Alosa braschnikowi* — demonstrated that seals consume fish ranging from 30 to 260 mm in length.

Keywords: Caspian Seal, fish, otolith, diet analysis, food habbits, Kendirli Haul-Out Site, feces, reconstruction of fish lengths.

Introduction

Caspian Seal (*Pusa caspica*) — the only mammal endemic to the Caspian Sea, listed in the IUCN Red List as a species facing the threat of extinction. It is also included in the List of Rare and Endangered Animal Species of Kazakhstan. Similar endangered status is attributed to the species in other Caspian countries [1-2].

It was believed that the Caspian Seal (*Pusa caspica*) was a dangerous predator, feeding on valuable commercial fish, as expressed by many fishermen and seal hunters [3-4]. Previous studies on the Caspian Seal's diet relied on animal slaughters and stomach content analysis [3–6]. According to Smirnov [5], out of 7 dissected stomachs with food remnants, 5 contained bullheads, and 2 contained crustaceans. Based on this, he hypothesized that the Caspian Seal primarily fed on bullheads.

Based on the available data from the studies conducted in the 1930s, the diet of the Caspian Seal during the winter period primarily consisted of bullheads, to a lesser extent atherinas, sprats, mollusks, and crustaceans; commercially important fish species such as zander were rarely encountered [4].

Roganov [7] presents data on the diet of the Caspian Seal during the spring period: in April, the Caspian Seal primarily feeds on sprat, despite the abundance of observed herring and bleak. Research by Roganov [8] during late autumn, winter, and early spring periods shows that the seal's diet comprises bullheads, atherinas, gammarids, and crustaceans. In early spring, sprats dominate the Caspian Seal's diet. According to his findings, commercially important fish species such as zander, herring, and bleak are very rare in their diet and are more of an exception.

Badamshin [4] largely corroborates the findings of predecessors. Based on data from 1939–1946, it was established that during the autumn-winter and spring periods, bullheads and sprats prevail in the Caspian Seal's diet. Gammarids, shrimps, and mollusks were also found in their diet.

There are records indicating that the Caspian Seal consumes small fish ranging from 3 to 15 cm in length [9]. It has also been noted that seal aggregations often occur in areas dominated by non-commercial fish species [10]. Caspian Seals are particularly abundant in the central and southern Caspian Sea, where their diet consists of sprats, bullheads, and atherinas [11-12].

In the 1930s to the 1970s, due to increased fishing, the availability of sprat as a food source for the Caspian Seal decreased [13]. In the 1990s, there was a decline in the Caspian Seal's prey base due to the introduction of the *Mnemiopsis leidyi* in the Caspian Sea, which further reduced sprat populations [14]. With the

decrease in sprat in the Caspian Sea, the proportion of bullheads in the Caspian Seal's diet increased [15]. Overall, the reduction in the seal's diet could be one of the factors contributing to its declining population. Hence, the continuation of research on the Caspian Seal's diet remains highly relevant. Due to the endangered status of the species, hunting seals is prohibited; instead, studies on pinniped diets are conducted through the collection of their feces [16–18].

Studies on seal distribution in recent years have indicated that the Kendirli Haul-Out Site in the Middle Caspian Sea, which was previously inhabited by seals, is no longer frequented by them [19-20]. However, fecal samples were collected from this site for several years, and the analysis of these samples is presented in the current study.

The goal of this study was to assess the diet of seals resting at the Kendirli Haul-Out Site. To achieve this objective, the following tasks were undertaken: conducting a comparative analysis of the Caspian Seal's diet seasonally and between different years, as well as reconstructing the size ranges of certain fish species consumed by seals, based on otoliths extracted from fecal samples.

Experimental

Fecal samples of seals (Fig. 1) were collected at the Kendirlihaulouts from 2015 to 2019. Fecal samples were collected and processed using the following methodology [21].

A — dried Caspian seal fecal matter *B* — sample label

Figure 1. Collection of fecal samples

To identify otoliths from fecal samples, preparatory work was conducted, including the creation of a collection, otolith descriptions, and the development of a methodological guide for studying fish otoliths with an accompanying atlas [22]. In this study, the identification of otoliths from Benthophilus genus and *Neogobius caspius*, which were not covered in the aforementioned guide for studying fish otoliths [23], was performed using existing collection materials. Formulas for reconstructing the lengths of certain species were calculated to determine the sizes of fish consumed by seals. The study employs zoological length measurements of fish, ranging from the tip of the snout to the end of the tail fin, in millimeters. In this study, formulas and calculation data are provided for two parameters: the length (OL) and width (OW) of otoliths from fecal samples. Certain differences in calculated data were observed based on these two parameters. The formulas for reconstruction based on otolith length and width, respectively, are as follows:

for *Neogobius melanostomus affinis*, $y = 0.145x + 28.829$, $y = 0.4589x + 34.116$;

for *N. pallasi* $y = 0.0331x + 29.406$, $y = 0.1611x + 32.663$;

for *Alosa braschnikowi*, $y = –5.5295x + 107.5$, $y = –3.4433x + 182.79$ [24–26].

A total of 70 fecal samples were collected and processed (Table 1). Apart from otoliths, the fecal samples from seals contained fish bones (vertebrae, jaws, pharyngeal teeth, and other bones), fish scales, fragmented parts of mollusk shells, and remnants of shrimp chitinous coverings. However, the specific identification of animals based on these structures proved challenging. Additionally, there was a group of unidentified fish otoliths that were difficult or impossible to attribute to any specific species. These otoliths from fecal samples had undergone deformation or damage during the seals' digestion process, resulting in the loss of identifying features necessary for their classification.

In this study, the analysis of seal diet is conducted solely based on identified fish otoliths.

Table 1

Information on dates of collection at the Kendirli haulouts, number of fecal samples and their primary treatment

Date	Number of fecal samples	Otoliths recovered, pcs.
19.05.15	1	17
31.10.15	8	141
30.08.16	4	44
30.04.17	19	587
11.10.17	15	1307
10.04.19	6	566
15.04.19	2	41
26.04.19	15	530
Total	70	3233

Restoration of fish length from otoliths found in faeces was done using formulas derived from a graph of the ratio of fish length to otolith length and width to otolith length and width [24].

Results

The fish species identified from otoliths in fecal samples collected from the Kendirli Haul-Out Site include 11 types: *Alosa (braschnikowi) braschnikowi* (Borodin, 1904) — Caspian herring, *Clupeonella caspia* Svetovidov, 1941 — Caspian sprat, *Chelon auratus* (Risso, 1810) — golden grey mullet, *Atherina caspia* Eichwald, 1831 — Caspian atherina, *Neogobius caspius* (Eichwald, 1831) — Caspian goby, *Neogobius melanostomus affinis* (Eichwald, 1831) — Caspian round goby, *Neogobius pallasi* (Berg, 1916) — Caspian sand goby, *Ponticola gorlap* (Iljin, 1949) — Caspian bighead goby, *Ponticola syrmaneurystomus* (Kessler, 1877) — Syrman goby, *Proterorhinus nasalis* (De Filippi, 1863) — tubenose goby, *Hyrcanogobius bergi* Iljin, 1928 — Volga dwarf goby. Additionally, fish from the Cyprinidae family and species from the genus *Benthophilus* Eichwald, 1831, are present in the diet. However, their specific identification is challenging at this stage of the research.

For the comparative analysis of the seal diet across seasons, unidentified otoliths from gobies of the genus Benthophilus and fish from the Cyprinidae family were provisionally counted as separate fish species (1 species for the Benthophilus genus and 1 species for the Cyprinidae family).

During the spring period at the Kendirli Haul-Out Site, the diet of the Caspian Seal consists of 5 to 12 fish species. Caspian atherina predominates in the seal's diet, constituting 23.5 % to 58.9 % and averaging 51.2 % across all years of the study. Gobiidae, comprising 7 species, account for 31.9 % to 35.3 % and average 33.0 % of the seal's diet over the entire study period. It is noteworthy that sprat dominated the diet only in one sample from 2015, accounting for 1.2 % of the overall diet over the years of study. Mullet and carp species were scarce, with herring being observed only once throughout the study years (Table 2).

Table 2

Diet Composition of the Caspian Seal in Spring (2015–2019)

№	Species	19.05.2015		30.04.2017		10–26.04.19		2015–2019	
		Number of pieces	%	Number of pieces	%	Number of pieces	%	Number of pieces	%
1	*Alosa braschnikowi*	0	0.0	0	0.0	1	0.1	1	0.1
2	*Clupeonella caspia*	7	41.2	4	0.7	10	0.9	21	1.2
3	*Chelon auratus*	0	0.0	17	2.9	2	0.2	19	1.1
4	*Atherina caspia*	4	23.5	217	37.0	670	58.9	891	51.2
5	*Neogobius caspius*	2	11.8	1	0.2	4	0.4	7	0.4
6	*Neogobius melanostomus affinis*	3	17.6	27	4.6	251	22.1	281	16.1
7	*Neogobius pallasi*	1	5.9	60	10.2	81	7.1	142	8.2
8	*Ponticola gorlap*	0	0.0	32	5.5	6	0.5	38	2.2
9	*Ponticola syrmaneurystomus*	0	0.0	31	5.3	34	3.0	65	3.7
10	*Proterorhinus nasalis*	0	0.0	6	1.0	3	0.3	9	0.5

Continuation of Table 2

11	Benthophilus	0	0.0	30	5.1	3	0.3	33	1.9
12	Cyprinidae	0	0.0	0	0.0	5	0.4	5	0.3
13	Unidentified fish otoliths	0	0.0	162	27.6	67	5.9	229	13.1
	Total	17	100	587	100	1137	100	1741	100

In the autumn diet, there is lower species diversity, typically ranging from 4 to 10 fish species. Among these, 8 species belong to the Gobiidae family. Goby species consistently dominate the diet both in terms of variety and otolith occurrences, constituting 54.6 % to 84.3 % annually and averaging 81.3 % across all years. Mullet is also found in the diet annually, but it was significantly abundant only in 2015, accounting for 1.1 % to 2.3 % of the otoliths in the seal's diet in other years. Over the entire study period, its contribution to the diet is estimated at 3.7 %. Caspian atherina plays a negligible role, making up only 0.5 % of the diet (Table 3).

Table 3

Diet Composition of the Caspian Seal in Autumn (2015–2017)

№	Species	31.10.2015 г.		30.08.2016 г.		11.10. 17 г.		2015–2017 гг.	
		Number of pieces	%	Number of pieces	%	Number of pieces	%	Number of pieces	%
1	*Chelon auratus*	39	27.7	1	2.3	15	1.1	55	3.7
2	*Atherina caspia*	0	0	0	0	8	0.6	8	0.5
3	*Neogobius caspius*	0	0	0	0	12	0.9	12	0.8
4	*Neogobius melanostomus affinis*	23	16.3	0	0	174	13.3	197	13.2
5	*Neogobius pallasi*	20	14.2	20	45.5	285	21.8	325	21.8
6	*Ponticola gorlap*	0	0	0	0	153	11.7	153	10.3
7	*Ponticola syrmaneurystomus*	24	17	10	22.7	144	11.0	178	11.9
8	*Proterorhinus nasalis*	2	1.4	0	0	44	3.4	46	3.1
9	*Hyrcanogobius bergi*	1	0.7	0	0	169	12.9	170	11.4
10	Benthophilus	7	5	4	9.1	121	9.3	132	8.8
11	Unidentified fish otoliths	25	0.18	9	20.5	182	13.9	216	14.5
	Total	141	100	44	100	1307	100	1492	100

Comparison of the Caspian seal diet at the Kendirli haul-out site during the spring and autumn seasons revealed significant differences based on the seasons. In autumn, the primary food source consists of bullhead fishes. In spring, the seals consume more sprat, with bullhead fishes being the second most common in their diet. The spring diet is more diverse, including a small amount of carp, herring, and sprat, which are absent in the autumn diet.

In general, the annual diet of the Caspian seal consists predominantly of fishes from the Gobiidae family and atherina, with the occasional presence of mullet and sprat. Cyprinidae and herring are encountered in rare instances (Fig. 2).

The reconstruction of fish lengths indicated significant variability in the average length of consumed Caspian round goby, ranging from approximately 75.5 mm to 70.7 mm based on different estimations (Table 4). According to literature sources, round goby in the Caspian Sea can reach a length of 160 mm; however, its average length is about 60 mm, and sexual maturity is attained in the second year of life at a body length of 40–90 mm [27]. Consequently, it can be inferred that the Caspian seal primarily consumes sexually mature round goby.

The average length of consumed Caspian sand goby by the Caspian seal also shows significant variation, but averages at 74.6 mm or 71.7 mm (Table 5). Sexual maturity in sand goby is reached in the 2nd to 3rd year of life at a body length of 40–80 mm [27]. Consequently, it can be concluded that the Caspian seal primarily consumes sexually mature sand gobies.

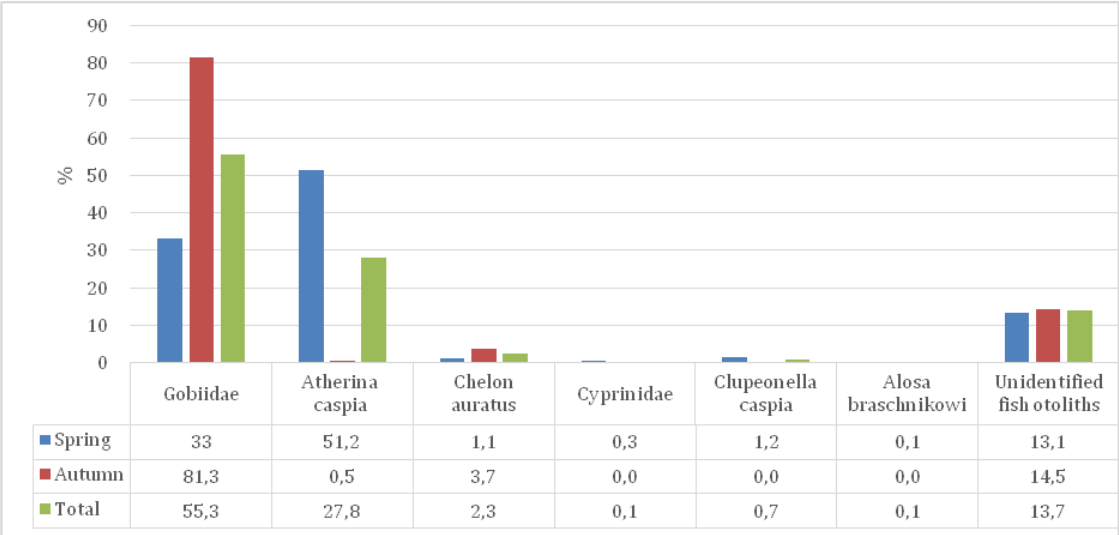

Figure 2. Analysis of the Caspian seal diet during the spring and autumn periods of 2015–2019 and overall for all years

Table 4

Reconstruction of Caspian round goby length (in mm) based on the length and width of otoliths found in fecal samples

Parameter	Fish length based on OL	Fish length based on OW
Minimum	33.2	34.7
Maximum	158.6	128.8
Average	75.5	70.7
Quantity	235	235

Table 5

Reconstruction of Caspian sand goby length (in mm) based on the length and width of otoliths found in fecal samples

Parameter	Fish length based on OL	Fish length based on OW
Minimum	38,3	39,2
Maximum	128,8	111,4
Average	74,6	71,7
Quantity	46	46

The reconstruction of the length of Caspian herring based on the length and width of a single otolith showed the consumed fish to be 259–262 mm long, respectively. In the Caspian Sea, spawning shoals of herring consist of fish ranging from 170 to 420 mm, with an average length of 270–320 mm [27]. From this, it can be inferred that the Caspian seal may consume sexually mature individuals of *A. braschnikowi* as part of its diet.

In general, the reconstruction of fish length has shown that the Caspian seal's diet includes fish of various species with lengths ranging from 30 to 260 mm.

Discussion

The overall dietary analysis reveals a similar diet pattern for the Caspian seal, consistent with previous studies: during autumn, Gobiidae species dominate their diet, while in spring, Caspian atherina are more prevalent. Additionally, Caspian spratare also observed in their diet during spring. However, as previously noted, the possible decrease in sprat biomass in the Caspian Sea might have influenced the Caspian seal's diet, as sprat otoliths were found in limited quantities. It is essential to consider that during the spring period, both atherina and sprat migrate along the coast of the Middle Caspian [28], where they become a part of the Caspian seal's diet. The abundance of atherinais likely due to the fact that this species is minimally exploited

by fishing activities [29], leading to a significant biomass in the sea [30]. This availability contributes to their prevalence in the Caspian seal's diet.

The materials obtained regarding the reconstructed lengths of fish in the diet of seals also confirm the data on the sizes of consumed fish from previous studies [4, 9].

Conclusion

The studies conducted on fish otoliths found in the feces of the Caspian seal have shown that the diet of Caspian seals at the Kendirli haul-out site primarily consists of fishes from the Gobiidae family. *Atherina caspia* plays a significant role in their diet, with a minor presence of *Chelon auratus*.

The inter-seasonal difference lies in the fact that in spring, *Atherina caspia* predominates in the diet of seals, while in autumn, eight species of Gobiidae fishes dominate. *Clupeonella caspia* was only found in spring and, overall, constituted a very insignificant portion of the diet, slightly over 1 %. Even less significant were *Alosa braschnikowi* and fishes from the Cyprinidae family, accounting for 0.1 % and 0.3 % respectively.

Significant attention is drawn to the considerable presence of unidentified otoliths, comprising approximately 14 % annually. We anticipate that with the intensified comparative analysis and the expansion of the collected materials, this percentage will decrease. This reduction is expected due to the inclusion of otoliths that have not completely lost their shape during the process of digestion.

In essence, the presented materials provide the first insights into the feeding habits of seals residing in the Middle Caspian and indicate their minimal impact on commercial fish resources.

This study may prove valuable in the future for evaluating the seals' habitat when devising conservation strategies and restoring the Kendirli haul-out site.

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Каспий итбалықтарының (*Pusa caspica* Gmelin, 1788) Кендірлі жатағында (Ортаңғы Каспий) шоғырланған кездегі қоректенуі

Каспий итбалығының Кендірлідегі жатағы Орта Каспийдегі жалғыз жатақ болғандықтан, итбалықтардың қоректенуі туралы мәліметтер Каспий итбалықтарының популяциясын зерттеу және сақтау үшін өте маңызды. Жұмыста Кендірлі жатағынан 2015–2019 жылдар аралығында жиналған нәжіс негізінде Каспий итбалығының қоректенуіне талдау жүргізілді. Каспий итбалығының «қызыл кітаптық» мәртебесіне байланысты қоректенуді нәжістік зерттеудің «тірідей» деп аталатын әдісі қолданылды. Каспий итбалығының маусым және жыл мезгілі бойына қоректенуіне салыстырмалы талдау жүргізіліп, итбалықтар жеген балықтардың ұзындықтары нәжістегі отолиттерді пайдалану арқылы қалпына келтірілді. Каспий итбалықтарының Кендірлідегі жатақтарындағы қоректік рационында балықтың 11 түрі бар екендігі анықталды, олардан басқа, *Cyprinidae* тұқымдасының балықтары, сондай-ақ түрлерге дейін анықталмаған *Benthophilus* тұқымдасы бар. Каспий итбалығының қорегі жыл мезгіліне байланысты әр түрлі болатындығы анықталды: күзде итбалықтың негізгі қоректену базасы мұңгір сияқты балық түрлерімен, ал көктемде *Atherina caspia*-мен көп мөлшерде қоректенетіні; сонымен қатар, көктемде күзде кездеспейтін *Cyprinidae, Clupeonella caspia* және *Alosa braschnikowi* тұқымдас балықтарымен қоректенеді. *Neogobius melanostomus affinis, Neogobius pallasi* және *Alosa braschnikowi* сияқты балықтың 3 түрі бойынша балық ұзындығының диапазонын қалпына келтіруде итбалық балықты 30-дан 260 мм-ге дейін тұтынатынын көрсетті.

Кілт сөздер: Каспий итбалығы, балықтар, отолиттер, қоректенуді талдау, рацион, Кендірлі жатағы, нәжіс, балықтың ұзындығын қалпына келтіру.

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Питание каспийского тюленя (*Pusa caspica* Gmelin, 1788) во время залегания на Кендирлинском лежбище (Средний Каспий)

Кендирлинское лежбище каспийского тюленя являлось единственным в Среднем Каспии, поэтому полученные данные по питанию тюленя являются важными для изучения и сохранения популяции каспийского тюленя. В данной работе был проведен анализ питания каспийского тюленя по сборам фекалий на Кендирлинском лежбище с 2015 по 2019 годы. В связи с «краснокнижным» статусом каспийского тюленя был использован прижизненный метод копрологического анализа питания. Проведен сравнительный анализ питания каспийского тюленя по сезонам, годам, восстановлены длины рыб, поедаемых тюленями, по отолитам из фекалий. Было установлено, что рацион питания каспийского тюленя на Кендирлинском лежбище представлен 11 видами рыб, кроме них в питании присутствуют рыбы семейства *Cyprinidae*, а также рода *Benthophilus*, неидентифицированные до видов. Установлено, что рацион питания каспийского тюленя различен в зависимости от сезона года: осенью основной кормовой базой тюленя являются бычковые виды рыб, а весной в питании большую часть занимает *Atherina caspia*; помимо этого, весной в питании встречаются рыбы семейства *Cyprinidae*, *Clupeonella caspia* и *Alosa braschnikowi*, которые отсутствуют осенью. Восстановление диапазонов длин рыб по 3 видам рыб: *Neogobius melanostomus affinis*, *Neogobius pallasi* и *Alosa braschnikowi* показало, что в пищу тюлень потребляет рыб от 30 до 260 мм.

Ключевые слова: каспийский тюлень, рыбы, отолиты, анализ питания, рацион, Кендирлинское лежбище, фекалии, восстановление длины рыб.

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