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RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

The length and weight relationships and feeding ecology of knout goby, *Mesogobius batrachocephalus* (Pallas, 1814) from Southern Black Sea

Güney Karadeniz'den kayabalığı *Mesogobius batrachocephalus* (Pallas, 1814) türünün boy-ağırlık ilişkileri ve beslenme ekolojisi

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Abstract: Among ecologically diverse gobies species, knout goby, *Mesogobius batrachocephalus* (Pallas, 1814), or previously known as *Gobius batrachocephalus*, is a Black Sea endemic species. There are studies on this species biological features along the Black Sea but there are only studies on its length and weight relationship along the Turkish coasts of the Black Sea. This study aims to contribute to the lack of knowledge on knout goby length and weight relationship and feeding ecology inhabiting Southern Black Sea. Total of 470 individual of knout goby was collected and it was previously reported that knout goby shows negative (-) allometry though within this study it was found that it only shows negative (-) allometry in spring and positive (+) allometry in other seasons. The diet was composed of crustaceans, teleost fishes and gastropods. According to the relative importance analysis, teleost fishes are the main food item for all and male individuals but for female crustaceans are the main food item. Trophic level results show that for all individuals trophic levels is 4.34, and when sexes are compared females have higher trophic level than males. While both sexes only consume teleost during summer, in other seasons females prefer more crustacean in their diet compared to males. Niche breadth index results indicated that when all individuals diet was compared among seasons in winter the niche breadth was the broader and summer was the narrower, in case of females the broader was fall and for males it was winter. In conclusion, feeding ecology of knout goby changes between seasons and sexes but general prey groups remain the same

Keywords: Ecology, Length and Weight Relationships, Knout Goby, Mesogobius batrachocephalus, Southern Black Sea

Öz: Ekolojik olarak çok çeşitlilik gösteren kayabalığı türlerinden, daha önce *Gobius batrachocephalus* olarak bilinen kayabalığı *Mesogobius batrachocephalus* (Pallas, 1814) türü Karadeniz endemiği bir türdür. Karadeniz'de türün biyolojik özellikleri üzerine çalışmalar bulunmasına karşın Karadeniz'in Türkiye kıyılarından sadece boy-ağırlık ilişkilerine dair çalışmalar bulunmaktadır. Bu çalışma Karadeniz'de türün boy-ağırlık ilişkisi ve beslenme ekolojisi üzerine olan bilgi eksikliğine katkı sağlamayı hedelemektedir. Toplamda 470 birey toplanmış olup daha önce negatif (-) allometri gösterdiği rapor edilmiş olan kayabalığının bu çalışmada bahar döneminde negatif (-) ve diğer mevsimlerde positif (+) allometri gösterdiği tespit edilmiştir. Besinini krustaseler, teleost balıklar ve gastropodlar oluşturmaktadır. Göreceli önemlilik indeksi analizine göre tüm bireyler ve erkekler için teleost balıklar ve dişiler için krustaseler ana besin grubunu oluşturmaktadır. Tüm bireyler için trofik seviye 4.34 bulunmuş olup dişilerin erkeklerden daha yüksek trofik seviyeye sahip olduğu gözlemlenmiştir. Yazın her iki cinsiyette sadece teleost balıkları tercih etmelerine karşın diğer mevsimlerde dişiler erkeklerden daha çok krustaseleri tercih etmektedir. Niş genişliği indeks sonuçlarına göre mevsimler karşılaştırıldığında kışın en geniş ve yazın en dar olduğu, dişilerin sonbaharda ve erkeklerin kışın en geniş sonuçlara sahip olduğu bulunmuştur. Sonuç olarak, türün beslenme ekolojisi mevsimsel ve eşeyler arası değişiklik göstermekte ama genel besin grupları aynı kalmaktadır.

Anahtar kelimeler: Beslenme Ekolojisi, Boy-Ağırlık İlişkileri, kayabalığı, Mesogobius batrachocephalus, Güney Karadeniz

INTRODUCTION

Paratethyan gobies are restricted to the branches of the Marmara, Black and Caspian Seas and none permanently inhabits marine waters (Freyhof, 2011). Among this ecologically diverse species group, knout goby, *Mesogobius batrachocephalus* (Pallas, 1814), or previously known as *Gobius batrachocephalus* (Froese and Pauly 2019), is a Black Sea endemic found on sand or rock bottom of inshore habitats, estuaries, brackish- and freshwater lagoons (Freyhof, 2011). The species is commercially valuable in Turkish waters. According to Turkish Fishery Statics the fishery production of goby species is 63.3 tons. There are studies on this species biological features but there are only studies on its length and weight relationship along the coasts of Turkish coasts of the Black Sea (Demirhan and Can, 2007; Ak et al. 2009; Çalık and Erdoğan-Sağlam, 2017).

In fisheries management, knowledge on basic biology of a species is essential for its sustainable management. Length and weight relationships (LWRs) is therefore standard practice for any such management plan (Kohler et al. 1996; Schneider et al. 2000). LWRs results provide information on the species population dynamics in addition to a baseline for further studies and management plans. Additionally, in general, fish have the potential to integrate different characteristics of their habitats at spatial/or temporal scales, especially if they have a generalist feeding strategy, in which knout goby is (Rosca and Manzu, 2011), thus, the diet reflects

the prey availability and can be considered as a "sampling tool" representing the prey items available in its environment (Wootton, 1990). By examining diet composition of generalist feeders also makes it possible to monitor ecological changes due to outside factors such as climate change or other stressors in the habitat.

Aim of this study is to contribute to the study areas limited length and weight relationship knowledge and as a first for Southern Black Sea provide information on the feeding ecology of knout goby.

MATERIALS AND METHODS

470 individuals of knout goby were collected monthly with a trammel net with different mesh sizes (mesh sizes ranging between 17-24 mm) between April 2017 and March 2018 from the Southern Black Sea (Ordu province, 41°10'95.39'' N 37°17'24.78 E – 40°57'01.91'' N 38°18'59.73 E) (Figure1). Samples were brought to the laboratory fresh and morphological measurements were conducted. Total length measurements were made using a measuring board with a sensitivity of 1 mm, and weight measurements were taken with an electronic scale with a sensitivity of 0.01 g. After measurements, the individuals were dissected, the individual was cut from anus towards the head and the body cavity was exposed. Sex determinations were made through macroscopic observation of the gonad. Stomach contents were identified, separated, counted, and weighed. For identification of the stomach contents Fischer et al. (1987) and Aydın et al. (2013) were used.

Figure 1. Map of the study area

Each prey item was weighed and recorded to the nearest 0.01 g using an electronic scale. The LWRs were calculated by using power relationship in the following equation:

$$W = aL^b$$

Where W is the total weight (g); L is the total length (cm), while a and b are constants for each species or population (Schneider et al., 2000; Karachle and Stergiou, 2012). The constants were estimated by using the logarithm transformation of LWR dataset. The LWR were estimated for all, each sex and season. The b value, which indicates growth tendency, was tested with t-test (Zar, 1996) to verify whether it differs from the isometry at a 0.05 significance level.

All prey items found in the stomach were identified to the lowest possible taxonomic level. Analyses on diet comparison were made between sexes. To evaluate the importance of each prey item, percentage by number (N%), percentage by weight (W%), frequency of occurrence (FO%) and percentage index of relative importance (IRI%) were calculated (Hyslop, 1980). For each species, vacuity indices were calculated from the ratio of number of stomachs with prey items and total examined individuals.

Smith's, (1982) index was chosen to assess the niche breadth for two main reasons. Firstly, this method takes into account the availability of prey groups, and secondly it is less sensitive to selectivity of the prey groups that are of lower importance (Krebs, 2009).

$$FT = \Sigma(\sqrt{a_i p_i})$$

where FT is Smith's measure of niche breadth; pi is the proportion of individuals using prey category i; ai is IRI% of prey category i to the total prey composition.

Morisita index was chosen to calculate niche overlap between each sex and seasons.

$$C = \frac{2\sum_i^n p_{ij}p_{ik}}{\sum_i^n p_{ij}\left[{}^{(n_{ij}-1)}/_{(N_j-1)}\right] + \sum_i^n p_{ik}\left[{}^{(n_{ik}-1)}/_{(N_k-1)}\right]}$$

where C is Morisita's index of niche overlap between j and k; pij is proportion of prey category i to total prey composition used by a group j; pik is proportion of prey category i to total prey composition used by a group k; nij is number of individuals of group j that used prey category i; nik is number of individuals of group k that used prey category i; Nj and Nk are total number of species group j and k, respectively.

Trophic levels of all individuals as well as for both sexes, all and each season were estimated. All taxa found in the stomachs of examined individuals were classed under the prey categories as Crustacean, Teleost and Gastropod for easy comparison. Trophic level of identified groups and species were taken from FishBase (http://www.fishbase.org) (Froese and Pauly, 2019). IRI% of each taxon was used to calculate the proportional contribution of each taxon in a group. The contribution of each taxon and their trophic levels were then used to calculate weighted average trophic level of each prey group (Table 1). Afterwards, trophic levels of examined species were calculated by;

$$\mathrm{TL} = 1 + \left(\sum_{j=1}^{n} (IRI\%)_j * TL_j\right)$$

Where TLj is the trophic level of each prey category j; Pj is IRI% of prey category j (Pauly et al., 2000).

Table 1. Trophic level of identified groups from FishBase

Group code	Description	Trophic level
Gastropoda	Gastropods and unidentified crustaceans	2.1
Crustacea	Crustaceans and unidentified crustaceans	2.6
Teleostei	Teleost and unidentified crustaceans	3.5

All statistical analyses were performed by using Windows Office Excel software.

RESULTS

Total of 470 individual, 232 females and 238 males, of knout goby was collected. Length of all individuals ranged from 12.60-31.80 cm and weight ranged from 12.62-377.54 g (Table 2). The LWRs parameters for all individuals and both sexes by seasons are given in Table 3.

Table 2. Descriptive statistics of all, female, and male for overall and by seasons (O: overall; Sp: spring; Su: summer; F: fall; W: winter; ♀: females; ♂: males; Min: Minimum; Max: Maximum; SD: Standart deviation)

		All (470 individual)		♀ *(232 individual)*		♂ *(238 individual)*	
		TL (cm)	**W (g)**	**TL (cm)**	**W (g)**	**TL (cm)**	**W (g)**
O	**Min-Max**	12.60-31.80	12.62-377.54	13.50-31.80	27.77-357.2	12.60-31.80	12.62-377.54
	Mean±SD	23.12±4.69	129.31±75.89	23.02±4.44	128.54±73.03	23.22±3.97	130.07±77.18
Sp	**Min-Max**	13.5-31.75	28.01-30.88	13.5-31.20	29.8-305.8	14.10-31.70	28.01-302.76
	Mean±SD	25.37±4.07	164.63±64.54	25.65±3.14	172.47±56.76	24.93±5.23	152.29±74.21
Su	**Min-Max**	13.00-31.80	20.28-272.64	21.00-30.30	72.52-272.64	13.00-31.80	20.28-270.61
	Mean±SD	23.61±6.11	136.49±85.57	26.88±2.65	179.2±54.75	21.19±6.83	104.86±91.22
F	**Min-Max**	15.10-31.8	25.07-208.10	15.10-31.80	27.77-288.10	15.50-31.50	25.07-262.03
	Mean±SD	21.55±4.31	98.34±62.99	21.27±4.77	97.57±74.05	21.76±2.44	98.92±44.66
W	**Min-Max**	12.60-31.60	12.62-377.54	13.50-30.50	30.59-357.2	12.60-31.60	12.62-377.54
	Mean±SD	23.29±4.32	141.14±81.35	21.34±3.49	106.67±64.72	25.34±4.55	177.23±86.01

In total only 22% of the stomachs were full (spring 44%, summer 6%, fall 22% and winter 24%). The diet was composed of crustaceans *[(Brachynotus sexdentatus* (Risso, 1827), *Eriphia verrucosa* (Forskål, 1775)], Isopoda, *Liocarcinus navigator* [(Herbst, 1794), *Palaemon elegans* Rathke, 1837, *Palaemon serratus* (Pennant, 1777), *Upogebia pusilla* (Petagna, 1792), *Xantho poressa* (Olivi, 1792)), teleost fishes (*M. batrachocephalus*, *Neogobius melanostomus* (Pallas, 1814*), Gobius cruentatus* Gmelin, 1789, *G. niger* Linnaeus, 1758, *Merlangius merlangus* (Linnaeus, 1758), *Mullus barbatus barbatus* Linnaeus, 1758, *Symphodus melops* (Linnaeus, 1758), *Trachurus mediterraneus* (Steindachner, 1868)) and gastropods (*Tritia neritea* (Linnaeus, 1758)). According to the relative importance analysis, teleost fishes are the main food item for all and male individuals but for female crustaceans are the main prey (Table 4).

When seasons were compared, teleost fishes are the primary item and crustaceans are secondary, except summer where only teleost fishes were consumed. Crustacean consumption is highest in spring and lowest in summer. In case of gastropods, they were only consumed in fall, additionally, is the only season where all three groups were consumed. Trophic level results show that for all individuals it is 4.34, and when sexes are compared females have higher trophic level than males (Table 4).

Table 3. Length-weight relationships parameters of all, female, and male for overall and by seasons (♂: male; ♀: female; N: number of individuals; a: and b: population constants; r2: Regression coefficient; SE of b: Standard error of b; O; overall; Sp: spring; Su: summer; F: fall; W: winter)

		All	♀	♂
O	N	470	232	238
	a	0.0062	0.0062	0.0061
	b	3.13	3.13	3.12
	r^2	0.9606	0.9589	0.9633
	SE of b	0.0293	0.0428	0.0397
	Allometry	positive (+)	positive (+)	positive (+)
Sp	N	108	66	42
	a	0.0138	0.0179	0.0137
	b	2.88	2.81	2.86
	r^2	0.9223	0.8874	0.9503
	SE of b	0.0812	0.1253	0.1034
	Allometry	negative (-)	negative (-)	negative (-)
Su	N	47	20	27
	a	0.0076	0.0023	0.0076
	b	3.04	3.04	3.04
	r^2	0.9875	0.9473	0.9875
	SE of b	0.0510	0.1894	0.0607
	Allometry	positive (+)	positive (+)	positive (+)
F	N	184	79	105
	a	0.0065	0.0065	0.0065
	b	3.09	3.10	3.09
	r^2	0.9689	0.9772	0.9598
	SE of b	0.0410	0.0538	0.0623
	Allometry	positive (+)	positive (+)	positive (+)
W	N	131	67	64
	a	0.0044	0.0039	0.0037
	b	3.26	3.31	3.30
	r^2	0.9696	0.964	0.9643
	SE of b	0.0507	0.0792	0.0807
	Allometry	positive (+)	positive (+)	positive (+)

Table 4. Trophic levels and IRI % values of all, female and male individuals

	Trophic level	Taxon	Crustacea	Teleostei	Gastropoda
All	4.34	Overall	29.94	69.70	0.36
		Spring	67.66	32.34	0.00
		Summer	0.00	100.00	0.00
		Fall	22.21	75.79	2.01
		Winter	4.58	95.42	0.00
Female	4.47	Overall	51.62	47.41	0.98
		Spring	73.56	26.44	0.00
		Summer	0.00	100.00	0.00
		Fall	51.62	40.21	8.17
		Winter	2.81	97.19	0.00
Male	4.19	overall	11.06	88.94	0.00
		Spring	48.50	51.50	0.00
		Summer	0.00	100.00	0.00
		Fall	3.89	96.11	0.00
		Winter	9.35	90.65	0.00

Smith's (1982) niche breadth index results indicated that when all individuals diet was compared among seasons, in winter the niche breadth was broader and summer was narrower (spring 0.29, summer 0.14, fall 0.31, winter 0.32). In case of females, fall was broader with 0.32 (spring 0.26, summer 0.14 and winter 0.27) and for males with 0.27 it was winter (spring 0.24, summer 0.10 and fall 0.23). Results of Morisita's niche overlap analysis among all, both sexes and seasons showed that maximum overlap was observed between all individuals and females (0.96). The highest niche overlaps among seasons for all and females was fall and for males was winter (Table 5). Additionally, the result indicate that females have a broader diet than males, and female diet is the one that determines the overlap ratio between sexes.

Table 5. Morisita's niche overlap values among all, each sex and seasons

		All	Female	Male	Spring	Summer	Fall	Winter
All			0.96	0.92	0.72	0.16	0.95	0.91
Female		0.96		0.73	0.83	0.19	0.91	0.80
Male		0.92	0.73		0.36	0.12	0.92	0.93
All	**Spring**	0.72	0.77	0.54		0.06	0.49	0.40
	Summer	0.16	0.15	0.17	0.06		0.12	0.15
	Fall	0.95	0.88	0.91	0.49	0.12		0.93
	Winter	0.91	0.77	0.93	0.40	0.15	0.93	
Female	**Spring**	0.74	0.83	0.52		0.00	0.64	0.46
	Summer	0.19	0.19	0.17	0.00		0.17	0.26
	Fall	0.83	0.91	0.61	0.64	0.17		0.69
	Winter	0.84	0.80	0.76	0.46	0.26	0.69	
Male	**Spring**	0.33	0.28	0.36		0.16	0.06	0.14
	Summer	0.09	0.06	0.12	0.16		0.00	0.12
	Fall	0.81	0.66	0.92	0.06	0.00		0.87
	Winter	0.77	0.55	0.93	0.14	0.12	0.87	

DISCUSSION

When compared with studies previously conducted in the southeastern Black Sea by Demirhan and Can (2007), in the eastern Black Sea by Ak et al. (2009) and in the south-central Black Sea by Çalık and Erdoğan-Sağlam (2017) all reported that the species show negative (-) allometry and parameter b was 2.75, 2.74 and 2.78, respectively. In contrast to Demirhan and Can (2007) in this study value of b was over 3 (all 3.13, females 3.13 males 3.12) and shown positive (+) allometry, except during spring (all 2.88, females 2.81 males 2.86). But since Demirhan and Can (2007) sampling period was between January to June 2002 and which corresponds to end of winter, whole spring and early summer the negative (-) allometry results show parallelism with this study. Additionally, the negative (-) allometry during spring could be explain by species reproductive season being during spring (Roşca and Mânzu, 2011). Before the breeding period the feeding process is very intensive but during reproduction season the energy is directed to reproduction and feeding priority falls behind hence resulting innegative (-) allometry. But in knout goby within this study picks it up again during summer and parameter b values increase, and species start to show positive (+) allometry. In case of Ak et al. (2009) one-year sampling, and Çalık and Erdoğan-Sağlam (2017) sampling between September and April, negative (-) allometry results show contrast with this study. The differences in b values compare to these two studies might be the result of differences in length distribution in case of Ak et al. (2009) (184 individuals, length ranged between 5.5-18.0 cm), or in Çalık and Erdoğan-Sağlam (2017) case small sample size (37 individuals).

Knout goby is reported to feed mostly on bivalves, gastropods, amphipods, isopods, decapods, fishes and algae by previous studies (Roşca and Mânzu, 2011). According to Roşca and Mânzu (2011) species diet was composed of bivalves [*Mytilus galloprovincialis* Lamarck, 1819, *Mytilaster lineatus* (Gmelin, 1791)], gastropods [*Setia valvatoides* (Milaschewitsch, 1909), *Hydrobia sp., Bittium sp.*], amphipods, isopods [(*Idotea balthica* (Pallas, 1772)], decapods (*X. poressa*), fishes (*Mullus barbatus ponticus* Essipov 1927, gobiids), chironomid larvae and algae. However, in this study even though there are bivalves like *M. galloprovincialis* in the Turkish coasts of Black Sea no bivalve was found in the diet composition, but as a mollusk gastropod were present. Additionally, the teleost predation of knout goby was more diverse compare to teleost species reported by Roşca and Mânzu (2011). As these result show knout goby feeds mainly on mollusk, crustacean and teleost fishes but diet composition of prey species (not taxa) changes according to prey availability as previously reported and also between sexes and seasons as well. Additionally, the trophic levels of all, female and males were found to be 4.34, 4.47, and 4.19, respectively. Previously reported tentative trophic level of the species was 4.20 (Froese and Pauly, 2019) which is little lower than what has been estimated within. Higher results obtained here could be related to the species preference of teleostei species where some are located in high trophic levels (such as *M. merlangus euxinus* and *T. mediterraneus*)

Generally small value for the niche breadth shows prey specialization of a species for a small number of prey (Roşca and Mânzu, 2011). Though Roşca and Manzu (2011) estimated niche breath from Levin's Index and only studied individuals for three seasons (spring, summer and fall) they reported niche breath as 0.115 during the fall of 2008 and 0.588 during the summer of 2009. Minimal Levin's index value indicates that the species diet is more specialise, and when it is maximum it is broadest. Keeping this on mind, Roşca and Manzu (2011) index values imply that during fall the diet of knout goby is more specialise and according to the diet composition from 2008, it is mainly bivalve, *M. galloprovincialis*, and in fall 2009 it is mainly isopods, *I. balthica*. Unlike Roşca and Manzu (2011), in this study, the results show that (even though the Smith (1982) niche breath index was used) knout goby diet is more specialised during summer and broader in fall and values are the highest in winter. In conclusion, feeding ecology of knout goby changes between seasons and sexes but general prey groups remain the same.

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