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On the Use of Otoliths of a Ponto-Caspian gobiid *Proterorhinus marmoratus* (Pallas, 1814) from Lake İznik (Turkey) in Prey-Predator Studies

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Abstract

The regression relationships between otolith morphometric parameters and body size in tubenose goby *Proterorhinus marmoratus* (Pallas, 1814) captured from Lake İznik in October 2004 were researched and determined. The equations were used to reconstruct the original dimensions of prey from the size of hard structures found in food samples of piscivorous predators living in, or in the vicinity of, the aquatic habitat. The relationships between the chosen hard structure and body length were described with various linear or non-linear equations. All calculated regressions were highly significant ($P<0.001$), except for the relationship of otolith length against total weight (female), and displayed a high coefficient of determinations ranging between 0.75 and 0.99. The linear function and non-linear functions provided the best fit for 62.5% and 37.5%, respectively. Analyzing the morphometric relationships, it is concluded that otolith length and otolith weight are good indicators of the total length and weight of tubenose goby. These data will help researchers studying food habits of top predators to determine the size and weight of prey fish from length and/or weight of recovered otoliths.

Key words: *Proterorhinus marmoratus*, otolith, predator, prey, Lake İznik

INTRODUCTION

Reconstruction of the original lengths of prey fish from the undigested remains of predators is an essential component for accurate estimates of the prey's biomass, and for determining their vulnerable size range [1-4]. Of the various methods developed for estimating the proportion of prey consumed by predators, the data expressed as biomass is usually considered as the most reliable method of quantifying actual diet composition [5-7]. This requires an estimation of the number of individual prey items taken, as well as their length and weight, both usually back-calculated from regressions based on the measurements of species-specific bones found in the feaces or gut. Such data not only helps identify possible species or size preferences within diet, it can also help identify preferred foraging sites or habitats, important when the fish taken are of economic value. Additionally, the length of a fish can be verified when the determined age from the otolith lies outside expected values. It can be extrapolated from the otolith length. Growth rate can also be determined [8].

Tubenose goby, *Proterorhinus marmoratus* (Pallas, 1814) is naturally distributed in lakes, rivers and lagoons, as well as seas in the Marmara and Black Sea regions in Turkey [9]. The Ponto-Caspian gobies have invaded several water bodies in Eastern Europe [10] and America [11] and their impact on native species of the Middle Danube potentially replicate that observed in the Great Lakes of North America, where the number of native fish species has declined in areas where gobies have become abundant [12]. In Lake İznik, tubenose goby is an important prey of several top-predator species among the large fishes, seabirds and watersnakes (unpubl. data). Since gobiids can play such an important role in the ecology of freshwater and brackish water ecosystems, their consumed biomass, other quantitative aspects of food consumption and potential effects for natural predation should be known. Identification and reconstruction of fish prey from otoliths in gobiids is relatively easy because of its dense structure and characteristic diagnostic features.

There have been several studies to estimate original lengths and weights of prey consumed by predators using fish otoliths [13-20]. However, to the best of our knowledge no information is available on the otolith morphometry - fish size relationship on tubenose goby. So our main aim was to establish several relationships between otolith morphometry and body size of tubenose goby captured in Lake İznik. These data might be used by researchers studying food habits of top predators to determine the size and weight of fish-prey from length, and/or weight of recovered otoliths.

MATERIAL AND METHODS

Lake İznik is located in the eastern part of the Marmara region and is the fifth largest lake in Turkey (area: 300 km^2; maximum depth: 65 m) [21]. Tubenose goby individuals were collected from western part of Lake İznik using beach seines in October 2004. All specimens were stored frozen. After the fish were thawed, total length (TL; most anterior point of head to most posterior tip of the caudal fin) and standard length (SL; most anterior point of head to the base of hypural plate at caudal exion) were measured to the nearest 0.01 millimeter with a digital caliper. Sagittal otoliths were removed, cleaned, and stored dry in vials. They were then weighed to the nearest 0.0001 g on a digital balance. Lengths of sagittae were determined using an eye-piece micrometer under a dissecting microscope (Olympus SZ-60). The otolith length was recorded as the greatest distance measured from the anterior rostrum to the posterior edge (Figure 1). Linear, $Y = ax + b$ and non-linear, $Y = ax^b$, (power model) regression equations were fitted to determine what equations best described various relationships between otolith and fish size. Those relationships were adopted that clarified the highest coefficient of determination (r^2) in each case. The significance of the regressions was assessed by an analysis of variance (ANOVA) testing the hypothesis H_0: $\beta=0$ against H_A: $\beta\neq0$ [22]. To permit comparisons with different equations derived from other locations, total length (TL) were regressed against standard length (SL). Regressions were tested for the differences between sexes using analysis of covariance (ANCOVA) [22].

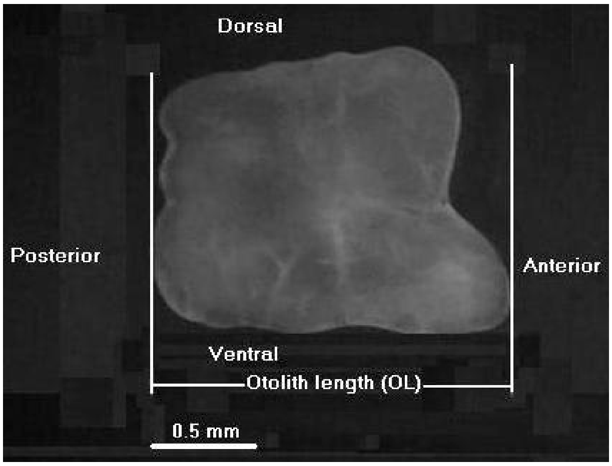

Figure 1. External view and terminology used throughout the text in the descriptions of sagittal otolith of tubenose goby from Lake İznik.

RESULTS

A total of 107 specimens (49 female, 53 male and 5 juveniles) were studied. Minimum, maximum and the mean total length and weight of fishes and otoliths were given in Table 1. No significant differences (t-test for paired comparisons, P>0.30) were noted between left and right otolith length and weight; therefore, the mean of the right and left measurements were used for the calculation of equations.

Table 1. Descriptive statistics for total length (TL), standard length (SL), total weight (TW), otolith weight (OW) and otolith length (OL) of tubenose goby captured in Lake İznik.

ALL INDIVIDUALS	TL (mm)	SL (mm)	TW (g)	OW (g)	OL (mm)
Minimum	23,39	17,63	0,1025	0,0001	0,8667
Maximum	73,89	59,48	4,5987	0,0020	1,8667
Mean	42,46	34,18	0,9523	0,0006	1,2184
Standard deviation (±)	11,27	9,21	0,8790	0,0004	0,1963
FEMALE	**TL (mm)**	**SL (mm)**	**TW (g)**	**OW (g)**	**OL (mm)**
Minimum	23.39	18.33	0.1337	0.0001	0.8667
Maximum	70.65	58.54	3.8074	0.0019	1.6667
Mean	45.07	36.36	1.1623	0.0006	1.2440
Standard deviation (±)	11.59	9.51	0.9294	0.0004	0.2001
MALE	**TL (mm)**	**SL (mm)**	**TW (g)**	**OW (g)**	**OL (mm)**
Minimum	23.55	19.21	0.1236	0.0001	0.8667
Maximum	73.89	59.48	4.5987	0.0020	1.8667
Mean	41.32	33.2110	0.8058	0.0005	1.2157
Standard deviation (±)	9.87	7.9909	0.7967	0.0003	0.1859

Table 2. Results from ANCOVA for the slope of different relationships between otolith and body size of tubenose goby from Lake İznik. Total length (TL), Standard length (SL), Total weight (TW), Otolith weight (OW) and Otolith length (OL)

OW vs.TW	OL vs.TL	OW vs.TL	OL vs.TW	OW vs.OL	SL vs.TL
o	xx	o	x	o	o

o = P>0.05, x = P<0.01, xx = P<0.005

Relationships in otolith length vs. total length, and otolith length vs. total weight were significant (P<0.005). However, no significant (P>0.05) relationship was determined in otolith weight vs. total weight, otolith weight vs. otolith length, otolith weight vs. total length and standard length vs. total length (Table 2).

All relationships between otolith and fish size were represented by figures (Figure 2) and equations (Table 3). A total 8 regression equations were obtained for the relationships, based upon highest coefficient of determination (r^2). The linear function and non-linear functions provided the best fit for 62.5% and 37.5%, respectively. All regressions were highly significant (p<0.001) except for the relationship of otolith length against total weight (female) (P=0.534), and all gave a coefficient of determination between 0.75 and 0.99 (see Table 3).

Table 3. Number of specimens (n), regression slope (b), intercept values (a), and coefficients of determination (r^2) for linear and non-linear relationships between otolith morphometric parameters and fish size of tubenose goby from Lake İznik. All regressions were significant at P<0.001 except for OL vs. TW (female).

Relationship	Type of regression	a	b	r^2	n	F
OW vs. TW	Linear	-0.2344	2132.300	0.851	107	125.5
OL vs. TL						
Female	Linear	-20.010	52.323	0.823	53	757.1
Male	Linear	-16.290	47.429	0.811	49	849.3
OW vs. TL	Linear	27.257	27309.000	0.850	107	1519.8
OL vs. TW						
Female	Non-linear	0.3371	4.5012	0.800	53	0.39
Male	Non-linear	0.2771	4.2383	0.751	49	12.2
OW vs. OL	Non-linear	5.8145	0.2040	0.828	107	4060.7
SL vs. TL	Linear	0.8078	1.2184	0.993	107	34.6

DISCUSSION

Prenda and Granado-Lorencio [7] have suggested that simultaneous use of several bone structures (opercula, cleithra, and pharyngeal bones) notably increases the probability of prey identification in predator feaces. This is equally true whether the presence/absence or the minimum number of individuals is being calculated. However, the use of multiple hard structures can raise the problem of overestimation of individuals in a predator stomach [23]. In the present study, otoliths are currently recognized as one of the most useful tools to reconstruct original size of prey fish in food samples of predators. However, otoliths are exposed to a variable degree of chemical and mechanical abrasion in the digestive track of predators. Hence, small otoliths are likely to be totally dissolved and thus some species may fail to be detected. On the other hand, partial digestion will bias estimates of prey size [6, 17, 24]. In addition to acid digestion, otoliths can become physically damaged during the process of ingestion by predators or during sample collection and processing, in which case reconstructing fish size and even identifying the prey can become impossible. This may be truth for cyprinids which have relatively small otoliths [20].

Left and right of the otoliths can not be of identical property for the reconstruction of the prey fish length. The use of paired bones increases the probability of assessing the minimum numbers of a species. However, left and right sides of otoliths can be paired only if they are the same size and shape. In the present study, there were no significant differences between left and right otoliths of a pair, therefore, there appears to be no need to specify which side of the fish was used when back-calculating length from otolith size.

Linear functions were usually adequate to describe relationships between fish size and hard structure size [2-4, 7]. However, curvilinear relationships can also provide the best fit for some fishes [20, 25] as seen in the present study.

To our knowledge there are no published relationships between otolith size and fish size for tubenose goby, so we can not assess whether a geographic variation similar to that recorded in otolith exists.

All equations relating otolith variables to fish standard length and weight for studied tubenose goby specimens explained most of the large proportion of variance in the data. Analyzing the morphometric relationships, we concluded that otolith length and otolith weight are good indicators of fish total length and weight in tubenose goby. If otolith length is used, potential regression explained more than 80% of the data variation in female and sexes combined, while it was 75% in males. If otolith weight is used, potential regression explained more than 82% in all individuals.

Fish weight can also be estimated by two step procedures, first using a relationship between hard structure length and fish length and then applying a fish length/fish weight equation. Length-weight relationship of tubenose goby in Lake İznik can be obtained equation given in Tarkan et al. [26]. The use of two regressions instead of a single one may introduce additional errors [6]. However, there is generally considerable seasonal and geographical variation in fish size/fish weight relationships [27, 28]. Therefore, the use of two functions is recommended, when only one intends to estimate fish weight based on regressions derived for other areas.

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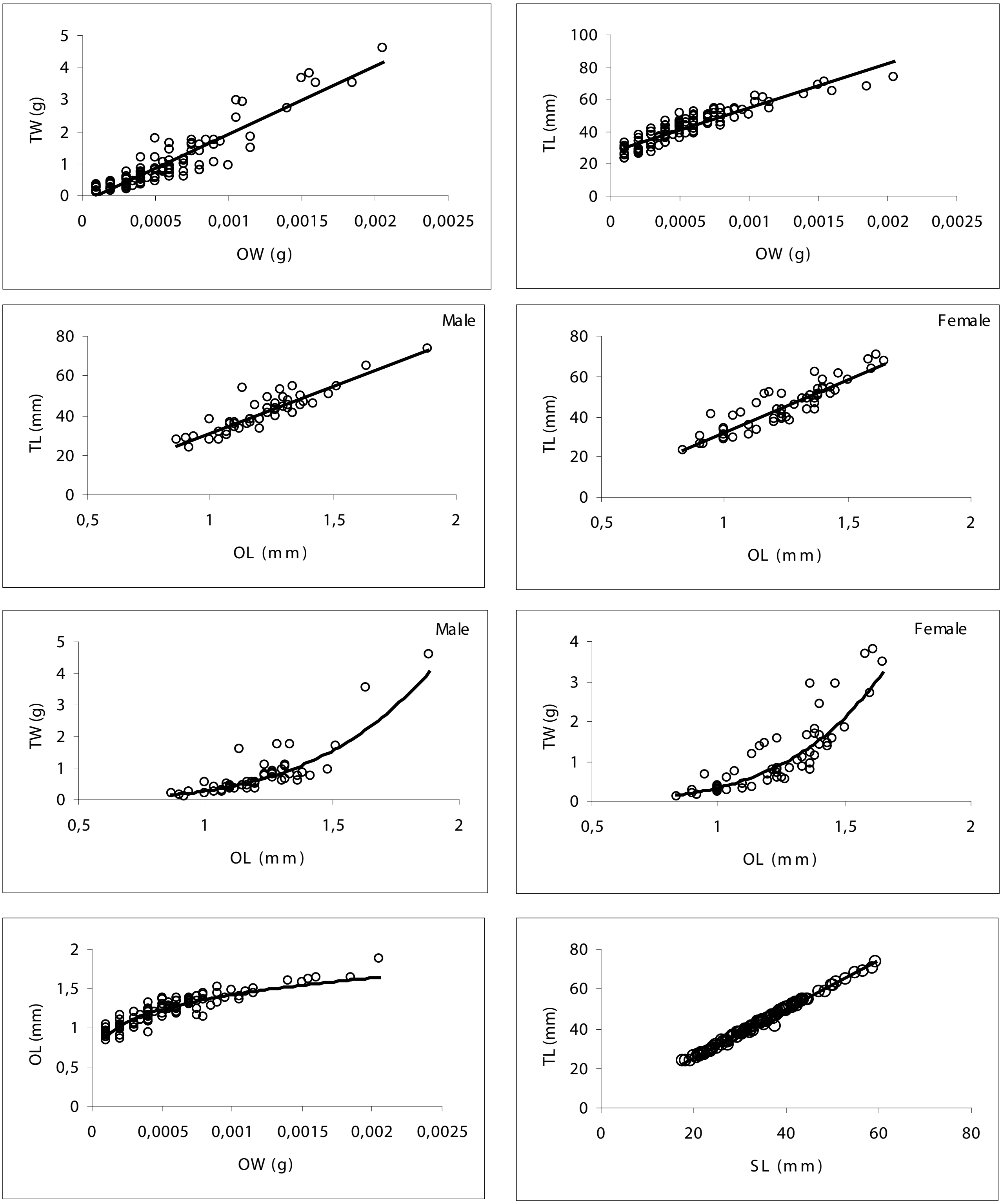

Figure 2. Relationships between otolith and fish sizes of tubenose goby in Lake İznik.

REFERENCES

[1] Popova O. 1967. The predator-prey relationship among fish. In: The Biological Basis of Freshwater Fish Production (ed Gerking SD), pp. 359-373. New York, John Wiley.

[2] Mann RHK, Beaumont WRC. 1980. The collection, identification and reconstruction of lengths of fish prey from their remains in pike stomachs. Fisheries Management. 11:169-172.

[3] Fickling NJ, Lee R. 1981. Further aids to the reconstruction of digested prey lengths. Fisheries Management. 12:107-110.

[4] Hansel HC, Duke SD, Lofy PT, Gray GA. 1988. Use of diagnostic bones to identify and estimate original lengths of ingested prey fishes. Transaction of the American Fisheries Society. 117: 55-62.

[5] Bekker DL, Nolet BA. 1990. The diet of otters *Lutra lutra* in the Netherlands in winter and early spring. Lutra 33:134-144.

[6] Pierce GJ, Boyle PR. 1991. A review of methods for diet analysis in piscivorous marine mammals. Oceanography and Marine Biology. An Annual Review 29: 409-486.

[7] Prenda J, Granado-Lorencio C. 1992. Biometric analysis of some cyprinid bones of prey fishes to estimate original lengths and weights. Folia Zoologica. 14:175-185.

[8] Spratt JD. 1975. Growth rate of the northern anchovy *Engraulis mordax*, in southern California waters calculated from otoliths California Fisheries and Game 61: 116-126.

[9] Geldiay R, Balık S. 2002. Freshwater Fishes of Turkey. (in Turkish). Ege Univiversity Press, İzmir-Turkey No:46, 532 pp.

[10] Naseka AM, Boldyrev VS, Bogustkaya NG, Delitsyn VV. 2005. New data on the historical and expanded range of *Proterorhinus marmoratus* (Pallas, 1814) (Teleostei: Gobiidae) in eastern Europe. Journal of Applied Ichthyology 21: 300-305.

[11] Jude DJ, DeBoe SF. 1996. Possible impact of gobies and other introduced species on habitat restoration efforts. Canadian Journal of Fisheries and Aquatic Sciences 53: 136-141.

[12] Crossman EJ, Holm E, Cholmondeley R, Tuininga K. 1992. First record for Canada of the rudd, *Scardinius erythrophthalmus*, and notes on the introduced round goby, *Neogobius melanostomus*. Canadian Field Natural 106: 206-209.

[13] Frost KJ, Lowry LF. 1986. Trophic importance of some marine gadids in northern Alaska and their body-otolith size relationships. Fishery Bulletin. 79: 187-192.

[14] Antonelis GA, Fiscus CH, Delong RL. 1984. Spring and summer prey of California sea lions, *Zalophus californianus* at San Miguel Island, California 1978-89. Fishery Bulletin. 82: 67-76.

[15] Härkönen TJ. 1986. Guide to otoliths of the bony fishes of the Northeastern Atlantic. 256p. Hellerup: Danbiu ApS.

[16] Jobling M, Breiby A. 1986. The use and abuse of fish otoliths in studies of feeding habits of marine piscivores. Sarsia. 71: 265-274.

[17] Echeverria T. 1987. Relationship of otolith length to total length in rockfishes from northern and central California. Fishery Bulletin. 85: 383-387.

[18] Gamboa DA. 1991. Otolith size versus weight and body-length relationships for eleven fish species of Baja California, Mexico. Fishery Bulletin 89: 701-706.

[19] Tollit DJ, Steward PM, Thompson PM, Pierce GJ, Santos MB, Hughes S. 1997. Species and size differences in the digestion of otoliths and beaks: Implications for estimates of pinniped diet composition. Canadian Journal of Fisheries and Aquatic Sciences. 54:105-119.

[20] Acıpınar H, Gürsoy Ç, Gaygusuz Ö, Tarkan AS. 2004. The Use and Suitability of Some Bone Measures and Otoliths For Size-Estimation of Fish In Predator Prey Studies. Behaviour and Ecology of Freshwater Fish: Linking Ecology and Individual Behaviour International Conference 22-24 August 2004. Freshwater Centre, Silkeborg, Denmark.

[21] Budakoğlu M, Bürküt Y. 1995. Trend surface and cluster analysis of İznik Lake surface water. The Symposium on Mining Chemistry. 7-10 November, 1995, İstanbul, Turkey: 117-124.

[22] Zar JH. 1999. Biostatistical analysis, 4^{th} eds. Prentice Hall, New Jersey. 663 pp.

[23] Hájková P, Roche K, Kocian L. 2003. On the use of diagnostic bones of brown trout, *Salmo trutta* m. *fario*, grayling, *Thymallus thymallus* and Carpathian sculpun, *Cottus poecilopus* in Eurasian otter, *Lutra lutra* diet analysis. Folia Zoologica 52:389-398.

[24] Pierce GJ, Boyle PR, Watt J, Grisley M. 1993. Recent advances in diet analysis of marine mammals. Symposium Zoological Society 66, 214-261.

[25] Radke RJ, Petzoldt T, Wolter C. 2000. Suitability of pharyngeal bone measures commonly used for reconstruction of prey fish length. Journal of Fish Biology 57:961-967.

[26] Tarkan AS, Gaygusuz Ö, Acıpınar H, Gürsoy Ç, Özuluğ M. 2006. Length-weight relationship of fishes from the Marmara region (NW-Turkey). Journal of Applied Ichthyology 22: 271-273.

[27] Moutopoulos DK, Stergiou KI. 2002. Length-weight and length-length relationships of fish species from the Aegean Sea (Greece). Journal of Applied Ichthyology 18:200-203.

[28] Koutrakis ET, Tsikliras AC. 2003. Length-weight relationships of fishes from three northern Aegean estuarine systems (Greece). Journal of Applied Ichthyology 19:258-260.