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Research article

The relationships between fish length and otolith measurements in *Alburnus derjugini* (Leuciscidae) and *Vimba vimba* (Leuciscidae) from the Harşit Stream, Türkiye

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Abstract: In this study, it was aimed to reveal the relationships between fish size and otolith length/height/width of *Alburnus derjugini* and *Vimba vimba* species sampled from Harşit Stream. A total of 80 specimens of *A. derjugini* and 71 specimens of *V. vimba* were collected. The relationships between the total length of fish and the otolith dimensions were determined using power models. Otolith length and otolith height/width were calculated for asteriscus and lapillus pairs in two species. The total length ranges of *A. derjugini* varied between 7.4-19.2 cm, and the total length of *V. vimba* ranged between 10.8-17.3 cm. When the relationships between total length and otolith length/height/width for asteriscus and lapillus were evaluated, the best fit was obtained among total length and asteriscus otolith height in *A. derjugini* (r^2>0.883) and *V. vimba* (r^2>0.746). In both species, while otolith measurements did not show statistically significant differences between sexes, right and left otolith measurements differed. For this reason, fish size-otolith measurements were calculated and evaluated separately for the right and left otoliths.

Keywords: *Alburnus derjugini*, *Vimba vimba*, Georgian shemaya, Vimba bream, otolith dimensions, Harşit Stream.

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Introduction

The Leuciscidae family is considered one of the largest and most diverse groups within the suborder Cyprinoidei (Leuciscinae in Eschmeyer et al., 2017). Fishes of this family exhibit a wide range of trophic diversity and associated morphology because of their widespread distribution in a variety of environments (Mayden, 1991; Kottelat & Freyhof, 2007; Gidmark & Simons, 2014). Despite a wide range in body size, it mostly consists of small fish (Page & Burr, 2011; Froese & Pauly, 2016). In this study, the species belonging to this family, *Alburnus derjugini* and *Vimba vimba* were examined. The distribution area of *A. derjugini* is Europe and Asia and covers the streams of the eastern Black Sea basin from Ashe drainage (Russia) to Harşit River (Türkiye) (Kottelat & Freyhof, 2007). Georgian shemaya (*A. derjugini*) is a fish species reported in the waters of Türkiye, especially from the Çoruh basin, but also recorded on the Harşit Stream (Bayçelebi et al., 2015). A member of the Leuciscidae family, the vimba bream (*V. vimba*) is a freshwater, brackish, benthopelagic fish. This species is distributed in Caspian, Black, Marmara and Baltic Sea basins. (Froese & Pauly, 2023). It is a potamodromous fish that inhabits in various types of waters (Kottelat & Freyhof, 2007; Hamáčková et al., 2009). Growth, reproduction, systematic features, biology, and nutrition of both species have been investigated (Okgerman et al., 2011; Bayçelebi et al., 2015; Magnıt & Yerli, 2018; Jalali et al., 2020; Kayiş et al., 2020; Saygun, 2021; Kujawa et al., 2022), but studies on otolith features of *V. vimba* are limited (Tarkan et al., 2007). To the authors' knowledge, no prior research has been done on the otolith characteristics of *A. derjugini*. As a result, this research will be the first examination of the relationship between fish length and otolith measurements of *A. derjugini*.

Otolith morphology is used in research on a wide range of fish biology subjects including fish anatomy, new fish species identification, taxonomic revisions of fish taxa, phylogenetic relationship analysis, eco-morphology studies, and comparisons of fish growth and otolith growth (Campana, 1999; Bostancı et al., 2012). Correlations between fish length and otolith parameters are used for a variety of purposes, including predation studies and fish growth (Park et al., 2018). Otolith size might be used to estimate fish total length because fish's growth has a noticeable significant effect and is correlated positively with otolith mass (Munk, 2012; Yılmaz et al., 2019). Otolith length and width measurements and their relationships are reliable taxonomic tools because they are utilized as identification criteria for fish otolith morphology (Lombarte et al., 2006). While examining the predator-prey relationship, otoliths are all that remains in the stomach in many prey species. By examining these otoliths, besides determining the size of the prey, they can also help in identification. The relationships between otolith sizes and fish size are currently used in the literature (Bostancı et al., 2017; Saygın et al., 2020; Nguyen & Dinh, 2020; Aufy et al., 2023).

In this study, it was aimed to reveal the relationships between otolith measurements and fish lengths of *A. derjugini* and *V. vimba* species sampled from Harşit Stream in Gümüşhane Province. Otolith morphometry may vary between species, as well as in populations of the same species living in different habitats (Reichenbacher et al., 2009). The findings of this research will give data for future studies on *A. derjugini* and *V. vimba* species. It will provide data for otolith characteristics, stomach content analysis studies, taxonomic studies, and archaeological studies regarding the species.

Material and Methods

The river network of Gümüşhane (Türkiye) consists of Harşit Stream (Doğankent) and Kelkit Stream and their branches. Harşit Stream passes through narrow and deep valleys and flows into the sea from Tirebolu after crossing Torul and Kürtün districts (Doğru et al., 1999). *Alburnus derjugini* and *V. vimba* samples were obtained from Harşit Stream in Torul District of Gümüşhane Province. A total of fish specimens were transported to the laboratory in 70% alcohol solution (Ichthyology Research Laboratory, Ondokuz Mayis University), where they were identified according to Çiçek et al. (2020, 2023) and Fricke et al. (2022). Total length of fishes was measured (±0.1 cm). By considering the structural differences of the gonads, sexes were determined macroscopically. A total of 80 *A. derjugini* specimens, 37 females and 43 males, and 71 *V. vimba*, 26 females and 45 males were captured during the sampling period. The asterisci and lapilli, which were exposed by cutting the skull, were removed from the skull by making right and left divisions. Otoliths were cleaned with distilled water and washed with 96% ethanol, then dried, and stored in Eppendorf tubes (Chugunova, 1963). Utricular and lagenar otoliths were photographed using the Leica DFC295 digital camera, discriminating between right and left. Digital images with high contrast were created. Each image was processed using the free ImageJ software (available at: http://rsb.info.nih.gov/ij/) to determine its pixel-cm ratio (Schneider et al., 2012). The otolith length (*OL*), otolith height (*OH*) and otolith width (*OWd*) were measured to accuracy of 0.001 mm, (Figure 1) according to Battaglia et al. (2010). Otolith measurements of *A. derjugini* were standardized as there was a significant difference between male and female individuals in terms of fish length. The formula, $M_s = m_o(\bar{x}/x)^b$, was used to standardize otolith measurements of *A. derjugini*. In the formula, $\mathrm{M_o}$ is the original otolith measurement, $\bar{x}$ mean of *TL* for all fish (*A. derjugini*, 13.92 cm), x is fish length of each sample, b is the allometric parameter (Lleonart et al., 2000; Zischke et al., 2016).

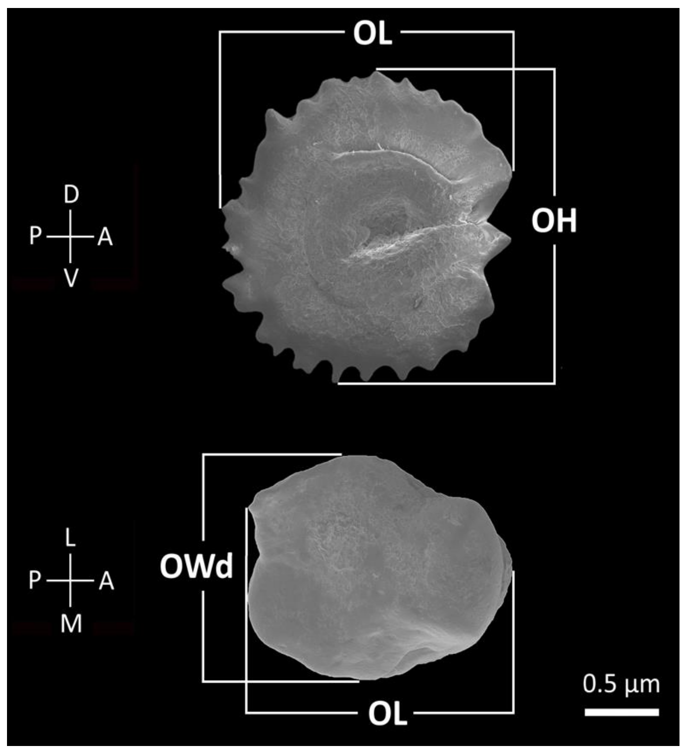

Figure 1. Left otolith measurements of *Alburnus derjugini* inhabiting Harşit Stream, (size of the fish *TL*: 13.50 cm; *OL*, otolith length; *OH*, otolith height; *OWd*, otolith width, *A*, anterior; *P*, posterior; *D*, dorsal; V, ventral; *L*, lateral; *M*, medial).

Normality tests of otolith measurements and fish length measurements were tested with the Kolmogorov-Smirnov test. The significance of sex-related difference in otolith measurements between male and female individuals was checked with the Mann-Whitney U test. Whether there was a difference in otolith measurements between right and left otoliths was tested with the Wilcoxon test. Since there was no difference in terms of otolith measurements of males and females, the relationships were determined for the general population in both species. To assess the relationships between the otolith measurements and total length (*TL*), power models ($y=ab^x$, where y is otolith length (*OL*)/ height (*OH*)/ width (*OWd*) and x is total length of fish) were used (Zar, 1999). All statistical tests were performed using IBM SPSS Statistics ver. 22, Minitab and the Excel software were used in the statistical analysis.

Results

Descriptive statistics of total length of *A. derjugini* (N=80) and *V. vimba* (N=71) individuals are presented in Table 1. While the average length was 13.92 cm for *A. derjugini* and 13.11 cm for *V. vimba* (Table 1). While there was no significant difference between male and female individuals in terms of total length in *V. vimba* (P=0.816, Mann Whitney U test), it was determined that the total length values of males and females were significantly different in *A. derjugini* (P=0.003, Mann Whitney U test).

Otolith measurements, descriptive statistics of asteriscus and lapillus of *A. derjugini* and *V. vimba* were offered separately for right and left otoliths in Table 2. When the otolith measurements of the right and left otoliths in *A. derjugini* were compared, it was determined that there was no difference in terms of asteriscus otolith length and otolith height ($P>0.05$), there was no difference in terms of lapillus otolith width ($P>0.05$), but there was a difference in otolith length ($P<0.001$). The otolith height ($P<0.001$) of the right and left asteriscus of the *V. vimba* and the otolith length of the right and left lapillus are significantly different from each other ($P<0.001$). Since there are differences in otolith measurements between right and left otoliths, otolith measurements-fish length relationships were analyzed separately for right and left otoliths.

Otolith measurements of asteriscus and lapillus of female and male individuals were compared by considering the right and left directions. According to the statistical analysis, otolith measurements were not different between sexes in both *A. derjugini* and *V. vimba* species. Standardized otolith measurements were used for comparisons between sexes. The relationships between otolith dimensions and fish length were shown in Figure 2 for *A. derjugini* in Figure 3 for *V. vimba*. All relationships are statistically significant ($P<0.001$). When the relationships between TL, OL, OH and OWd were examined, the best fit was obtained among TL and OH in *A. derjugini* for asteriscus ($r^2 > 0.883$). Similarly, in *V. vimba*, when all relationships were examined, the highest regression coefficients ($r^2> 0.746$) were found between otolith height of asteriscus and fish size.

Table 1. Descriptive statistics for total length (*TL*, cm) of *Alburnus derjugini* and *Vimba vimba* sampled from Harşit Stream. N: number of specimens, Sd: Standard deviation.

Species	Variable		N	Min.	Max.	Mean	±Sd
Alburnus derjugini	TL	Female	37	12.8	19.2	14.44	1.061
		Male	43	7.4	16.5	13.47	1.800
		All	80	7.4	19.2	13.92	1.571
Vimba vimba	TL	Female	26	11.5	17.3	13.22	1.464
		Male	45	10.8	15.7	13.04	1.027
		All	71	10.8	17.3	13.11	1.199

Table 2. Otolith dimensions (mm) of *Alburnus derjugini* (*n* = 80) and *Vimba vimba* (*n* = 71) sampled from Harşit Stream.

Localities	Otolith	Variable	Min.	Max.	Mean	±SD
Alburnus derjugini	Right Asteriscus	OL	1.106	2.765	2.129	0.228
		OH	1.150	2.706	2.063	0.218
	Left Asteriscus	OL	1.198	2.663	2.118	0.232
		OH	1.106	2.570	2.055	0.217
	Right Lapillus	OL	1.098	2.240	1.856	0.183
		OWd	0.832	1.810	1.513	0.167
	Left Lapillus	OL	1.103	2.148	1.828	0.171
		OWd	0.840	1.756	1.503	0.167
Vimba vimba	Right Asteriscus	OL	1.923	2.865	2.300	0.208
		OH	1.846	2.522	2.125	0.141
	Left Asteriscus	OL	1.948	2.826	2.301	0.194
		OH	1.825	2.501	2.105	0.146
	Right Lapillus	OL	1.567	2.258	1.826	0.133
		OWd	1.285	1.843	1.504	0.122
	Left Lapillus	OL	1.605	2.235	1.813	0.123
		OWd	1.272	1.787	1.503	0.116

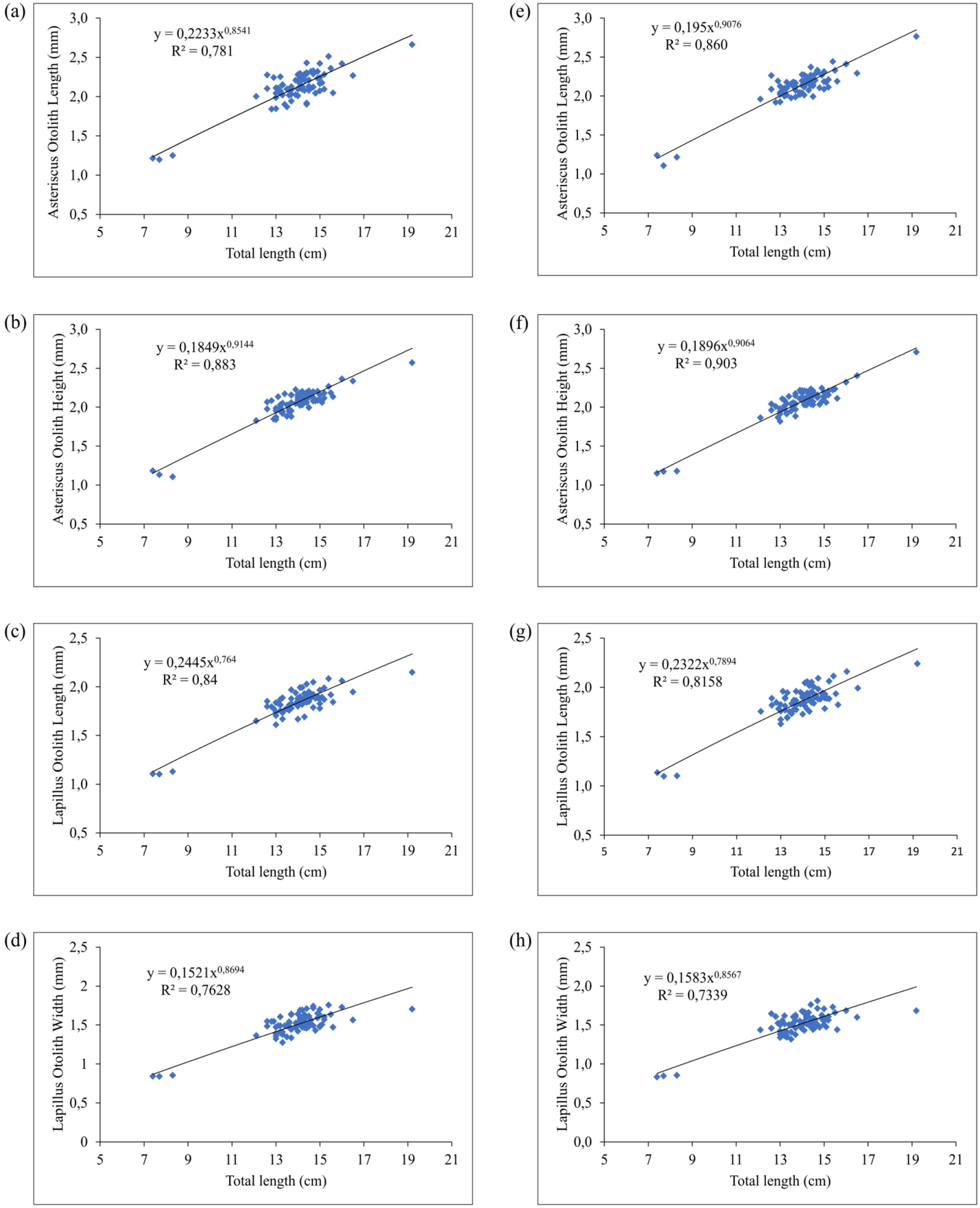

Figure 2. The relationships between otolith measurements and total length for *Alburnus derjugini*. (left otoliths: a, b, c, d, right otoliths: e, f, g, h

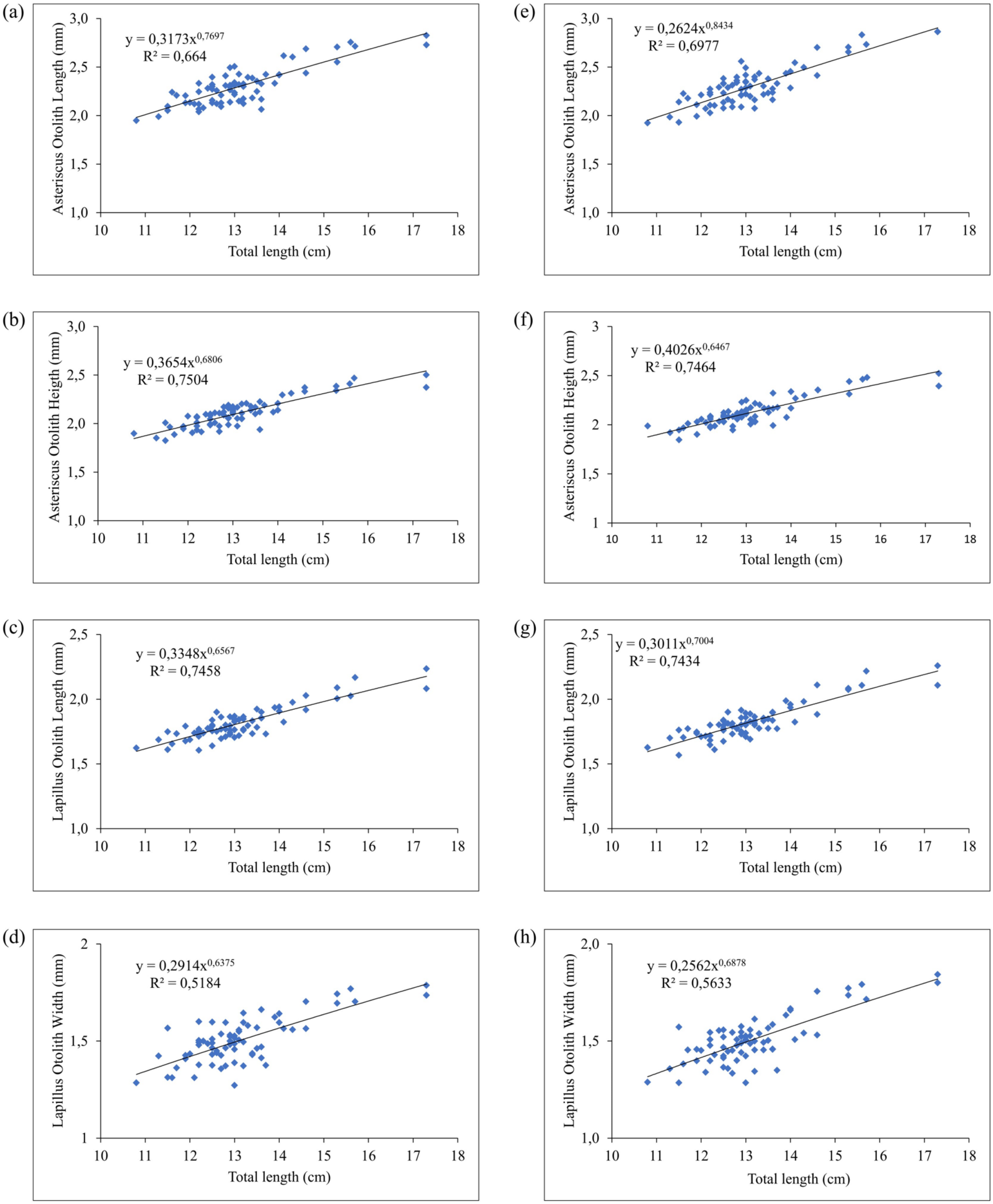

Figure 3. The relationships between otolith measurements and total length for *Vimba vimba*. (left otoliths: a, b, c, d, right otoliths: e, f, g, h)

Discussion

Otolith length and width measurements and the relationships obtained from these measurements are often used in keys and identification guides in the morphology of fish otoliths, making them useful taxonomic tools (Lombarte et al., 2006).

In the research examining the relationships between fish length and otolith measurements, there are studies examining not only the relationship between otolith length and fish length (Harvey et al., 2000, Sen et al., 2001), but also studies examining the relationship between fish length and otolith length, otolith height, or otolith width (Bostancı et al., 2017; Yedier, 2021; Pradhan et al., 2022; Athaa et al., 2023). It is expected that explaining the relationships by taking both measurements into account will provide more reliable results. Damage to the end parts of the otolith (rostrum or post-rostrum) is a more common situation. Therefore, if the end parts of the otolith are damaged, it becomes impossible to estimate fish length from otolith length. In this case, otolith height/width is used. In the results of this study, the highest regression coefficient in the relationships between fish length and otolith measurements was determined in the relationships between otolith height/width-fish length in *A. derjugini* and *V. vimba*. When the relationships equations between fish length and otolith measurements were examined, it was concluded that the regression coefficient obtained from each relationship equation was statistically significant ($P<0.001$). The results showed that fish length can be obtained reliably by using otolith length and otolith height/width, which are otolith variables for both species.

In this study, otolith measurements and fish size relationships of the species were examined according to both otolith pairs and sexes. No study has been found examining the otolith measurements-fish length relationships of the *A. derjugini*. For this reason, it is thought that the deficiencies in this regard regarding the species will be closed. Otolith measurements-fish length of *V. vimba* species was examined by Tarkan et al. (2007). In their study, the relationships between measurements of bony structures of *V. vimba* such as pharyngeal, operculum, cleitrum and otolith and fish length were examined using a non-linear equation. The regression coefficient values of the equations obtained from the relationships between otolith measurements and fish lengths are greater than 0.86. The study results are compatible with the results of this study. The values of otolith length, otolith height/width were standardized while comparing otolith measurements of *A. derjugini* for removing size effect. Numerous studies have also employed standardized data (Torres et al., 2000; Lombarte et al., 2010; Bani et al., 2013; Bostanci & Yedier, 2018; Saygın et al., 2020; Akbay et al., 2022)

The relationship of otolith measurements and total length were collected for *A. derjugini* and *V. vimba* in Harşit Stream, some for the first time. This study will be useful for stock studies and fisheries management studies on *A. derjugini* and *V. vimba* species.

Ethical Approval

All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

Conflicts of Interest

The authors declare that they have no conflict of interest.

Funding Statement

The author does not declare any fund.

References

Akbay, R., Yilmaz, S., Ozpicak, M., Saygin, S., & Polat, N. (2022). Lagenar otolith morphometry of gibel carp, *Carassius gibelio* (Cyprinidae): Comparisons among four populations in Samsun Province (Turkey). *Journal of Ichthyology*, 62(5), 770-776. https://doi.org/10.1134/S0032945222050022

Athaa, F. F., Partosuwiryo, S., & Probosunu, N. (2023). Correlation of otolith morphometrics with total length and weight of shortfin scad (*Decapterus macrosoma* Bleeker, 1851) in the Special Region of Yogyakarta. *Aquaculture, Aquarium, Conservation & Legislation*, 16(2), 957-969. http://www.bioflux.com.ro/aacl

Aufy, L. A., Al-Jumaiee, S. A., Al-Atbee, I. A., & Al-Mansy, K. A. (2023). The relationship between otolith dimensions and fish body size of *Nemipterus japonicus* (Bloch, 1791) in Iraqi marine water. *Journal of Survey in Fisheries Sciences*, 10(3S), 5209-5215. https://doi.org/10.17762/sfs.v10i3S.1764

Bani, A., Poursaeid, S., & Tuset, V. M. (2013). Comparative morphology of the sagittal otolith in three species of south Caspian gobies. *Journal of Fish Biology*, 82(4), 1321-1332. https://doi.org/10.1111/jfb.12073

Battaglia, P., Malara, D., Romeo, T., & Andaloro, F. (2010). Relationships between otolith size and fish size in some mesopelagic and bathypelagic species from the Mediterranean Sea (Strait of Messina, Italy). *Scientia Marina*, 74(3), 605–612. https://doi.org/10.3989/scimar.

Bayçelebi, E., Turan, D., & Japoshvili, B. (2015). Fish Fauna of Çoruh River and Two First Record for Turkey. *Turkish Journal of Fisheries and Aquatic Sciences*, 15, 783-794. https://doi.org/ 10.4194/1303-2712-v15_4_01

Bostancı, D., & Yedier, S. (2018). Discrimination of invasive fish *Atherina boyeri* (Pisces: Atherinidae) populations by evaluating the performance of otolith morphometrics in several lentic habitats. *Fresenius Environmental Bulletin*, *27*(6), 4493-4501.

Bostancı, D., Yedier, S., Kontaş, S., Kurucu, G., & Polat, N. (2017). Regional variation of relationship between total length and otolith sizes in the three *Atherina boyeri* Risso, 1810 populations, Turkey. *Ege Journal of Fisheries and Aquatic Sciences*, 34(1), 11-16. https://doi.org/10.12714/egejfas.2017.34.1.02

Bostanci, D., Yilmaz, S., Polat, N., & Kontaş, S. (2012). İskorpit *Scorpaena porcus* L. 1758'un otolit biyometri özellikleri. *Karadeniz Fen Bilimleri Dergisi*, 3(1), 59-68. https://dergipark.org.tr/en/pub/kfbd/issue/22230/238632

Campana, S. E. (1999). Chemistry and composition of fish otoliths: pathways, mechanisms and applications. *Marine Ecology Progress Series*, 188, 263-297. https://doi.org/10.3354/meps188263

Chugunova, N. I. (1963). *Age and growth studies in fish. Israel Program Scientific Translatin.* Washington D.C: National Science Foundation.

Çiçek, E., Sungur, S., & Fricke, R. (2020). Freshwater lampreys and fishes of Turkey; a revised and updated annotated checklist 2020. *Zootaxa*, 4809(2), 241-270. https://doi.org/10.11646/ZOOTAXA.4809.2.2

Çiçek, E., Sungur, S., Fricke, R., & Seçer, B. (2023). Freshwater lampreys and fishes of Türkiye; an annotated checklist-2023. *Turkish Journal of Zoology*, 47(6), 324-468.

Doğru, E., Kural, A., Pir, H., Aydın, C. A., & Bulgur, İ. (1999). *Cumhuriyet'in 75. Yılında Gümüşhane*. Ekspres Ofset, İstanbul.

Eschmeyer, W. N., Fricke, R., & van der Laan, R. (Eds.) (2017). *Catalog of Fishes*. http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp

Fricke, R., Eschmeyer, W. N., & van der Laan, R. (2022). *Eschmeyer's catalog of fishes: genera, species, references.* https://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp

Froese, R., & D. Pauly. (Ed.) (2023). FishBase. World Wide Web electronic publication. https://www.fishbase.se/summary/Vimba-vimba.html

Froese, R., & Pauly, D. (Eds.) (2016). FishBase. World Wide Web Electronic Publication. http://www.fishbase.org

Gidmark, N. J., & Simons, A. M. (2014). Cyprinidae: carps and minnows. In Warren, M. L., Jr. & Burr, B.M. (Eds.), *Freshwater Fishes of North America* (pp. 354-450). Johns Hopkins University Press.

Hamáčková, J., Prokeš, M., Kozák, P., Peňáz, M., Stanny, L. A., Policar, T., & Baruš, V. (2009). Growth and development of vimba bream (*Vimba vimba*) larvae in relation to feeding duration with live and/or dry starter feed. *Aquaculture*, 287(1-2), 158-162. https://doi.org/10.1016/j.aquaculture.2008.10.059

Harvey, J. T., Loughlin, T. R., Perez, M. A., & Oxman, D. S. (2000). *Relationship between fish size and otolith length for 63 species of fishes from the eastern North Pacific Ocean*. (Report No. NOAA Technical Report NMFS, 150). National Marine Fisheries Service.

Jalali, S., Jamili, S., Borani, M., Ramezanifard, E., & Sepahdari, A. (2020). Ontogenic development of digestive accessory glands in larval and juvenile Vimba bream, *Vimba vimba* (Pallas, 1814). *Iranian Journal of Fisheries Sciences*, 19(1), 99-110. https://doi.org/10.22092/IJFS.2019.118838

Kayiş, Ş., Bingöl, A., Er, A., & İpek, Z. Z. (2020). Parasitic examination of cultured trout species and Georgian shemaya (*Alburnus derjugini*) live in Kürtün Dam Lake. *Journal of Anatolian Environmental and Animal Sciences*, 5(2), 236-240. https://dergipark.org.tr/en/download/article-file/1154218

Kottelat, M., & Freyhof, J., (2007). *Handbook of European Freshwater Fishes*. Publications Kottelat.

Kujawa, R., Piech, P., Nowosad, J., & Kucharczyk, D. (2022). Comparison of different methods of wild vimba bream *Vimba vimba* (L.) spawning under controlled conditions. *Animal Reproduction Science*, 244, 107036. https://doi.org/10.1016/j.anireprosci.2022.107036

Lleonart, J., Salat, J., & Torres, G. J. (2000). Removing allometric effects of body size in morphological analysis, *Journal of Theoretical Biology*, 205, 85-93. https://doi.org/10.1006/jtbi.2000.2043

Lombarte, A., Chic, Ò., Parisibaradad, V., Olivellal, R., Piera, J., & Garcíaladona, E. (2006). A web based environment from shape analysis of fish otoliths. The AFORO database. *Scientia Marina*, 70: 147-152.

Lombarte, A., Palmer, M., Matallanas, J., Gómez-Zurita, J., & Morales-Nin, B. (2010). Ecomorphological trends and phylogenetic inertia of otolith sagittae in Nototheniidae. *Environmental Biology of Fishes*, 89, 607-618. https://doi.org/10.1007/s10641-010-9673-2

Mangit, F., & Yerli, S. V. (2018). Systematic evaluation of the genus *Alburnus* (Cyprinidae) with description of a new species. *Hydrobiologia*, 807(1), 297-312. https://doi.org/10.1007/s10750-017-3405-y

Mayden, R. L. (1991). Cyprinids of the New World. In I. J. Winfield & J. S. Nelson (Eds.), *Cyprinid Fishes: Systematics, biology and exploitation* (pp. 240–263). Springer Dordrecht.

Munk, K. M. (2012). *Somatic-otolith size correlations for 18 marine fish species and their importance to age determination* (Report No. 5J12-13). Regional Information Report.

Nguyen, H. D. T., & Dinh, Q. M. (2020). Otolith dimensions and their relationship with the size of *Glossogobius sparsipapillus* fish along the coastline of Mekong Delta, Vietnam. *Egyptian Journal of Aquatic Biology and Fisheries*, 24(2), 525-533. https://doi.org/10.21608/EJABF.2020.86013

Okgerman, H., Elp, M., & Yardimci, C. H. (2011). Growth, the length-weight relationship, and reproduction in vimba (*Vimba vimba* L. 1758) sampled from an oligo-mesotrophic lake in northwest Anatolia (Turkey). *Turkish Journal of Zoology*, 35(1), 87-96. https://doi.org/10.3906/zoo-0901-16

Page, L. M., & Burr, B. M. (2011). *Peterson field guide to freshwater fishes of North America North of Mexico*. Houghton Mifflin Harcourt, Boston.

Park, J. M., Gaston, T. F., Riedel, R., & Williamson, J. E. (2018). Biometric relationships between body and otolith measurements in nine demersal fishes from north-eastern Tasmanian waters, Australia. *Journal of Applied Ichthyology*, 34(4), 801-805. https://doi.org/10.1111/jai.13612

Pradhan, S. K., Sri Hari, M., Roul, S. K., Ghosh, S., Jaiswar, A. K., Nayak, B. B., & Bhusan, S. (2022). Relationship between fish and otolith dimensions of flathead sillago *Sillaginopsis panijus* (Hamilton, 1822) (Perciformes: Sillaginidae) in the north-western Bay of Bengal. *Indian Journal of Fisheries*, 69(3), 155-160. https://doi.org/10.21077/ijf.2022.69.3.102825-19

Reichenbacher, B., Kamrani, E., Esmaeili, H.R., & Teimori, A. (2009). The endangered cyprinodont *Aphanius ginaonis* (Holly, 1929) from southern Iran is a valid species: evidence from otolith morphology, *Environmental Biology of Fishes*, 86(4), 504-521. https://doi.org/10.1007/s10641-009-9549-5

Saygın, S., Özpiçak, M., Yılmaz, S., & Polat, N. (2020). Otolith shape analysis and the relationships between otolith dimensions–total length of European Bitterling, *Rhodeus amarus* (Cyprinidae) sampled from Samsun Province, Turkey. *Journal of Ichthyology*, 60, 570-577. https://doi.org/10.1134/S0032945220040190

Saygun, S. (2021). The new record native and non-native species for the ichthyofauna of Elekçi Stream (Turkey). Biy*olojik Çeşitlilik ve Koruma*, 14(1), 13-23. https://doi.org/10.46309/biodicon.2021.798644

Schneider, C. A., Rasband, W. S., & Eliceiri, K. W., (2012). NIH Image to ImageJ: 25 years of image analysis, *Nature Methods*, 9(7), 671-675. https://doi.org/10.1038/nmeth.2089

Sen, D., Aydin, R., & Calta, M. (2001). Relationships between fish length and otolith length in the population of *Capoeta capoeta umbla* (Heckel, 1843) inhabiting Hazar Lake, Elazig, Turkey. *Fisheries & Aquatic Life*, 9(2), 267-272.

Tarkan, A. S., Gursoy Gaygusuz, C., Gaygusuz, Ö., & Acipinar, H. (2007). Use of bone and otolith measures for size-estimation of fish in predator-prey studies. *Folia Zoologica Praha*, 56(3), 328.

Torres, G. J., Lombarte, A., & Morales-Nin, B. (2000). Sagittal otolith size and shape variability to identify geographical intraspecific differences in three species of the genus *Merluccius*. *Journal of the Marine Biological Association of the United Kingdom,* 80(2), 333-342. https://doi.org/10.1017/S0025315499001915

Yedier, S. (2021). Otolith shape analysis and relationships between total length and otolith dimensions of European barracuda, *Sphyraena sphyraena* in the Mediterranean Sea. *Iranian Journal of Fisheries Sciences*, 20(4), 1080-1096. https://doi.org/10.22092/ijfs.2021.124429

Yılmaz, S., Emiroğlu, Ö., Aksu, S., Başkurt, S., & Polat, N. (2019). Relationships between otolith dimensions and body growth of North African Catfish *Clarias gariepinus* (Burchell, 1822) from the upper basin of the Sakarya River, Turkey. *Croatian Journal of Fisheries*, 77(1), 57-62. https://doi.org/10.2478/cjf-2019-0006

Zar, J. H. (1999). *Biostatistical Analysis*. 4th ed. Prentice-Hall, New Jersey.

Zischke, M. T., Litherland, L., Tilyard, B. R., Stratford, N. J., Jones, E. L., & Wang, Y. G. (2016). Otolith morphology of four mackerel species (*Scomberomorus* spp.) in Australia: species differentiation and prediction for fisheries monitoring and assessment. *Fisheries Research*, 176, 39-47. https://doi.org/10.1016/j.fishres.2015.12.003