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Relationships between Otolith Dimensions and Total Length of Some Small-sized Fish Species from the Marmara Sea, Türkiye

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ABSTRACT

The small-sized adult and juvenile fish species have great ecological importance by means of the prey-predator relationship. Due to these species become prey of larger fish species, their otoliths are mostly seen in the stomach content of predators. The fish size-otolith size studies reveals robust data for estimating fish size from the otolith size. To contribute this aspect, the relationships between total length and otolith length (TL-OL), total length and otolith width (TL-OW), total length and otolith radius (TL-OR) of seven species (*Liza saliens*, *Pomatoschistus marmoratus*, *Pomatoschistus bathi*, *Pomatoschistus minutus*, *Synapturichthys kleinii*, *Chelidonichthys lucerna* and *Symphodus roissali*) were investigated. Species were obtained by beach-seine nets from 12 sampling stations in the shallow waters of the Marmara Sea. While calculating the relationships, linear regression analysis (y = bx + a) was used and the coefficient of determination (R^2) was identified. The R^2 values were usually seen as high in all equations. The highest values of R^2 for TL-OL and TL-OW were obtained from *P. minutus*, while the highest values of TL-OR detected were for *C. lucerna*. The lowest values of R^2 for TL-OW and TL-OR were obtained from *P. marmoratus*, while the lowest values of TL-OL were detected for *P. bathi*. This study revealed the first results for *P. minutus*, *S. kleinii*, *S. roissali* in the Turkiye Seas and for *P. bathi* in the worldwide by means of fish length – otolith size relationships.

KEYWORDS: Beach seine nets, Juvenile, Fish, Otolith size, Shallow waters

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1. Introduction

The inner ears of all teleost fishes contain calcified structures, which otoliths are balance and hearing organs (Popper et al., 2005). These structures serve as the life history of the species (Belchier et al., 2004). The otoliths continue to grow throughout the species life and do not resorb in times of stress (Yaremko, 1996; Mendoza, 2006). So, the analysis of the microstructure of the otolith is a reliable piece of information on the daily (Mendoza, 2006; Yazıcı et al., 2021), size (Campana and Jones, 1992), growth (Mendoza, 2006), sexual dimorphism (Cardinale et al., 2004; Yazici, 2023), stock identification (Campana, 2005), feeding ecology of predators (Campana and Casselman, 1993), and the determination of the migration direction (Kennedy et al., 2002) and ontogeny of fish species (Song et al., 2019). These informations contribute to fisheries management (Campana and Thorrold, 2001; McFarlane et al., 2010; Gerard and Malca, 2011). Also, otolith dimensions can be related to fish sizes (Pannella, 1971). These relationships are species-specific, but they may occur in different populations of species (Fey, 2006). According to Harvey et al. (2000), the relationship between fish length and otolith dimensions can be described by using a simple linear regressions.

Some valuable studies on fish size – otolith size relationships have been revealed in the literature (Harvey et al., 2000; Battaglia et al., 2010; Viva et al., 2015). These relationships were revealed for some species presented in this study in the Türkiye seas, as for *L. saliens* and *P. marmoratus* in the Aegean Sea (Akyol and Kınacıgil, 2001; Altin and Ayyildiz, 2018), for *P. marmoratus* and *Chelidonichthys lucerna* in the Black Sea (Gümüş et al., 2021; Hasimoğlu et al., 2016) and for *C. lucerna* in the Mediterranean Sea (Başusta and Bıyıklı, 2022).

The small-sized adult and juvenile fish species have a great ecological importance by means of the prey-predator relationship. Due to these species become prey of larger fish species, their otoliths are mostly seen in the stomach contents of predators. The fish size-otolith size studies reveals robust data for estimating of fish size from the otolith size. Between the seven species examined in this study, *P. marmoratus*, *P. bathi*, *P. minutus,* and *S. roissali* were small-sized adults and *C. lucerna, S. kleinii and L. saliens* were juveniles and originated as an important components of the coastal biodiversity of the Marmara Sea. Thus, we aimed to reveal the otolith size-fish size relationship of these species, which some of exhibit first data for the Marmara Sea (all 7 species), for Turkiye seas (*P. minutus*, *S. kleinii*, *S. roissali* and *P. bathi*) and for worldwide (*P. bathi*) in the literature.

2. Material and Methods

Individuals were sampled with beach seine nets from 12 equally-spaced sampling locations around the Marmara Sea, Türkiye between November 2021 and March 2022. All beach seine net tows were realized with 2 replications from shallow waters (0-5 meters) in day hours (Figure 1).

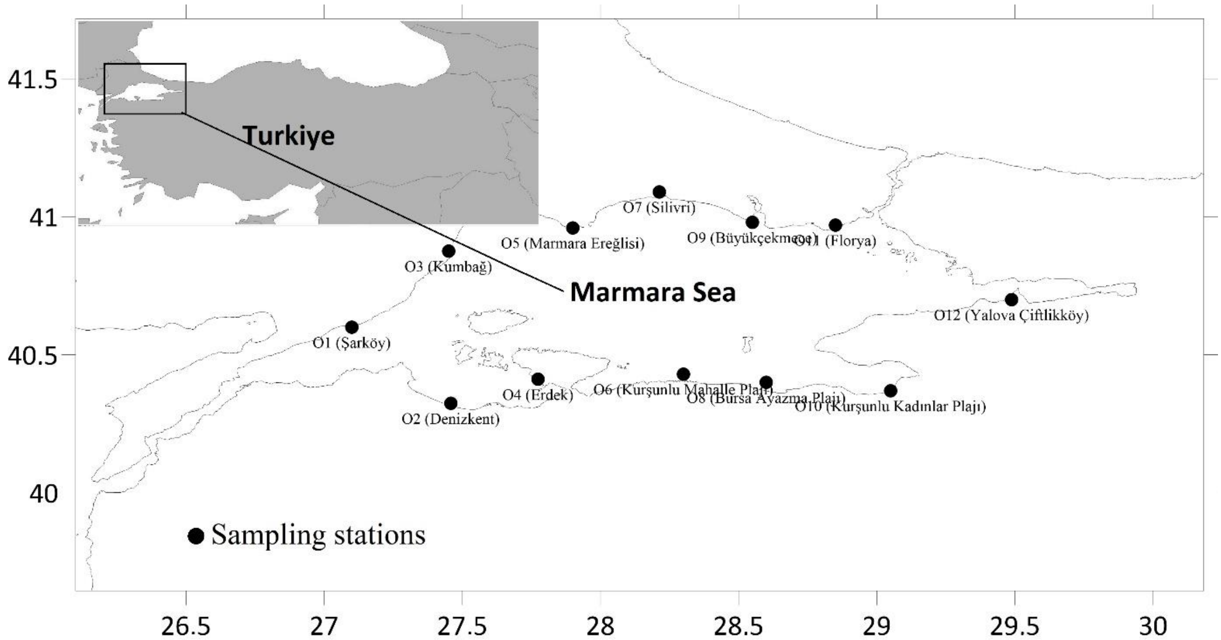

Figure 1. Study area and the sampling stations

The mesh size of the beach seine net was used as a 6.5 mm bar length in the wings and 4 mm bar length in the bag. The wings of this net had 15 m length, and the bag had 2 × 2 × 2 meters dimensions. So, the total length of this net was determined as approximately 32 m. The hanging ratio of the bag and wings were arranged as 0.85 and 0.66, respectively. In order to haul, 15 m of long warp was rigged for each wing. Synthetic polypropylene twine diameter ropes were used in hanging as 9 ⌀, leadline and floatline as 6 ⌀ and net as 2.5 ⌀. The individuals were kept in an ice-box and transported to the laboratuary, immediately. Species identification was realized according to Whitehead et al. (1986). The total length (TL) of individuals were measured with a digital caliper (Mitutoyo CD-15 APX) and the larger individuals were measured with a measuring board to the nearest 0.01 mm.

Sagittal otolith pairs of species were removed, cleaned, dried and stored in eppendorf tubes. These otoliths of species were photographed then measurements were made. The otolith length (OL), otolith width (OW) and otolith radius (OR) of individuals were measured to the nearest 0.001 mm with using stereomicroscope and Q-Capture digital imaging program, each right and left sagitta of each individual. The otolith length (OL) was recorded as the distance from the midpoint of the rostrum through the primordium to the posterior edge. The otolith width (OW) was recorded as the distance perpendicular to the length passing through the primordium (Javor et al., 2011). The otolith radius (OR) was determined by the distance from the otolith core to its margin (Zabel et al., 2010). These measurements were tested to identify whether the right and left otoliths were different. The student t-test (Zar, 1999) was used to compare between length, width and radius of the right and left sagittal otoliths. No significant differences of measurements were detected for all species ($p > 0.05$). These statistical analyses were done using the PAST Version 2.17 program (Hammer et al., 2001). So, right otoliths were used in regression analyses.

Linear regression analysis ($y = bx + a$) was used to determine the relationship between otolith dimensions and fish length (TL-OL; TL-OW and TL-OR) and the coefficient of correlation determination (R^2) were calculated.

3. Results

In this study, a total of 111, 113, 107, 6, 61, 7 and 8 individuals of *Liza saliens*, *Pomatoschistus marmoratus*, *Pomatoschistus bathi*, *Pomatoschistus minutus*, *Synapturichthys kleinii*, *Chelidonichthys lucerna* and *Symphodus roissali* were analyzed, respectively. Sample sizes for species ranged between 6 and 113 individuals. The individual number (n), minumum (min), maximum (max) and mean of TL, OL, OW, and OR of these species can be seen in Table 1. The mean otolith length and otolith radius of *S. kleinii* was smaller than other species. Also, the mean otolith width of *S. roissali* was smaller than other species. The small sizes were measured for *L. saliens* and *P. marmoratus* in OL (Table 1).

The equations of relationship between the total length and otolith dimensions of seven species are given in Table 2. Also, the equation curves of each species can be seen in Figures 2, 3, 4, 5, 6, 7 and 8, respectively. The R^2 values were detected usually high in all equations. The highest values of R^2 were obtained from *P. minutus* for the equations of TL-OL and TL-OW, while the highest values of R^2 were detected for *C. lucerna* in the equation of TL-OR.

The lowest values of R^2 were obtained for *P. marmoratus* for equations of TL-OW and TL-OR, while the lowest values of TL-OL were found for *P. bathi*. Although TL-OR coefficient relationships were weak, higher coefficient determination values were found for *P. minutus* from the equations of TL-OL and TL-OW. The highest R^2 values for all relationships were recorded for *L. saliens* (0.91, 0.88 and 0.91, respectively), while the lowest R^2 values were detected for *P. marmoratus* (0.76, 0.80 and 0.65, respectively) (Table 2). Although both two species were represented with the highest sample number, the R^2 values varied relatively higher. Thus, it was understood that the sample size was not a major determinant for R^2.

Table 1. The min, max and mean of TL, OL, OW, and OR of seven fish species

Species	N	Total length (mm)			Otolith length (mm)			Otolith width (mm)			Otolith radius (mm)		
		Min	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**
L. saliens	111	18.86	123.19	51.7	0.497	4.033	1.822	0.311	2.302	1.139	0.228	2.009	0.828
P. marmoratus	113	24.81	79.9	50.82	0.81	1.994	1.542	0.71	1.849	1.329	0.467	0.963	0.749
P. bathi	107	25.75	78.12	55.11	0.958	1.969	1.653	0.747	1.639	1.365	0.473	1.016	0.805
P. minutus	6	49.41	63.91	55.5	1.509	1.957	1.724	1.252	1.573	1.374	0.78	1.029	0.924
S. kleinii	61	26.57	125.16	73.02	0.543	1.942	1.193	0.42	1.654	1.058	0.251	1.005	0.607
C. lucerna	7	67.63	87.92	77.23	1.643	1.961	1.803	1.398	1.649	1.525	0.639	0.993	0.809
S. roissali	8	42.77	96.82	68.46	1.189	2.107	1.74	0.839	1.267	1.024	0.541	1.021	0.767

Table 2. The relationships between TL-OL, TL-OW, TL-OR of seven fish species

Species	TL-OL	R^2	TL-OW	R^2	TL-OR	R^2
L. saliens	TL=0.0381OL-0.1461	0.91	TL=0.0174OL+0.2434	0.88	TL=0.0177OL-0.0885	0.91
P. marmoratus	TL=0.0179OL+0.6298	0.76	TL=0.0151OL+0.5635	0.80	TL=0.007OL+0.3933	0.65
P. bathi	TL=0.0176OL+0.6817	0.75	TL=0.0142OL+0.5821	0.82	TL=0.0088OL+0.3186	0.81
P. minutus	TL=0.0294OL+0.0924	0.95	TL=0.0236OL+0.0638	0.97	TL=0.0147OL+0.1058	0.74
S. kleinii	TL=0.013OL+0.2465	0.92	TL=0.011OL+0.2577	0.87	TL=0.0077OL-0.0021	0.87
C. lucerna	TL=0.0138OL+0.7395	0.86	TL=0.0097OL+0.7737	0.90	TL=0.0169OL-0.4964	0.92
S. roissali	TL=0.0165OL+0.6105	0.88	TL=0.0085OL+0.4438	0.91	TL=0.0084OL+0.1929	0.85

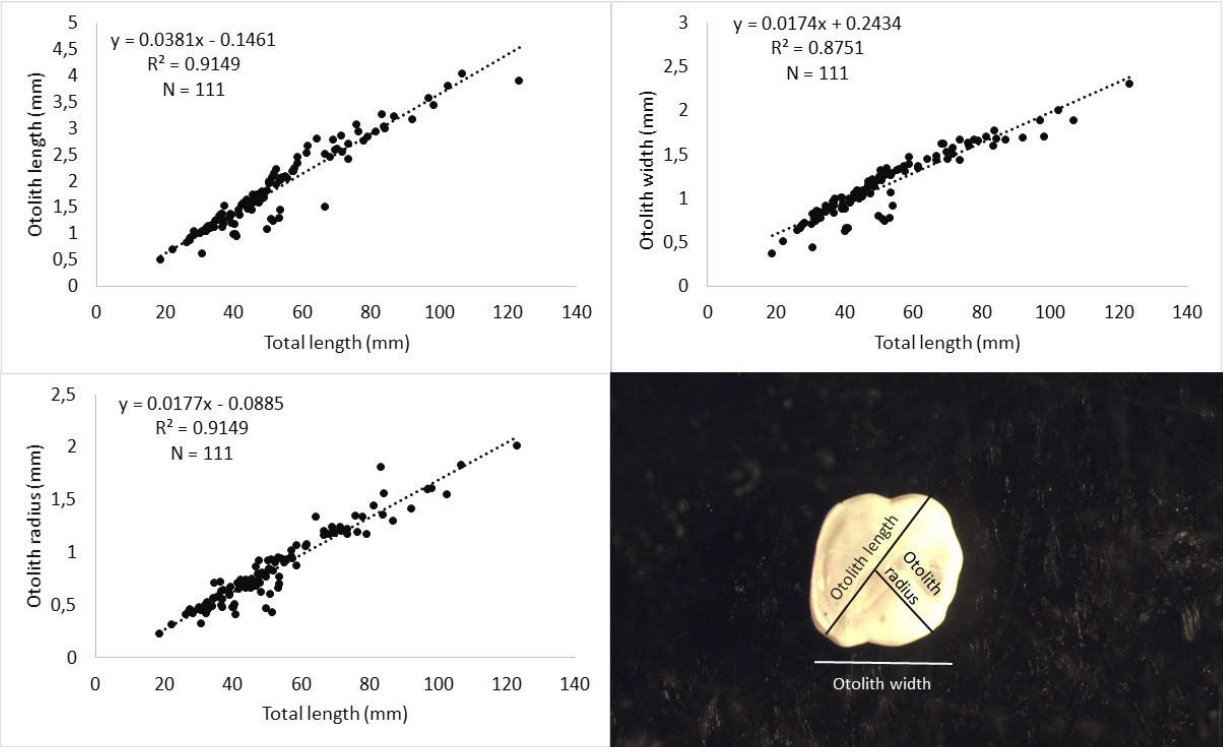

Figure 2. The relationships between TL-OL, TL-OW and TL-OR of *L. saliens*

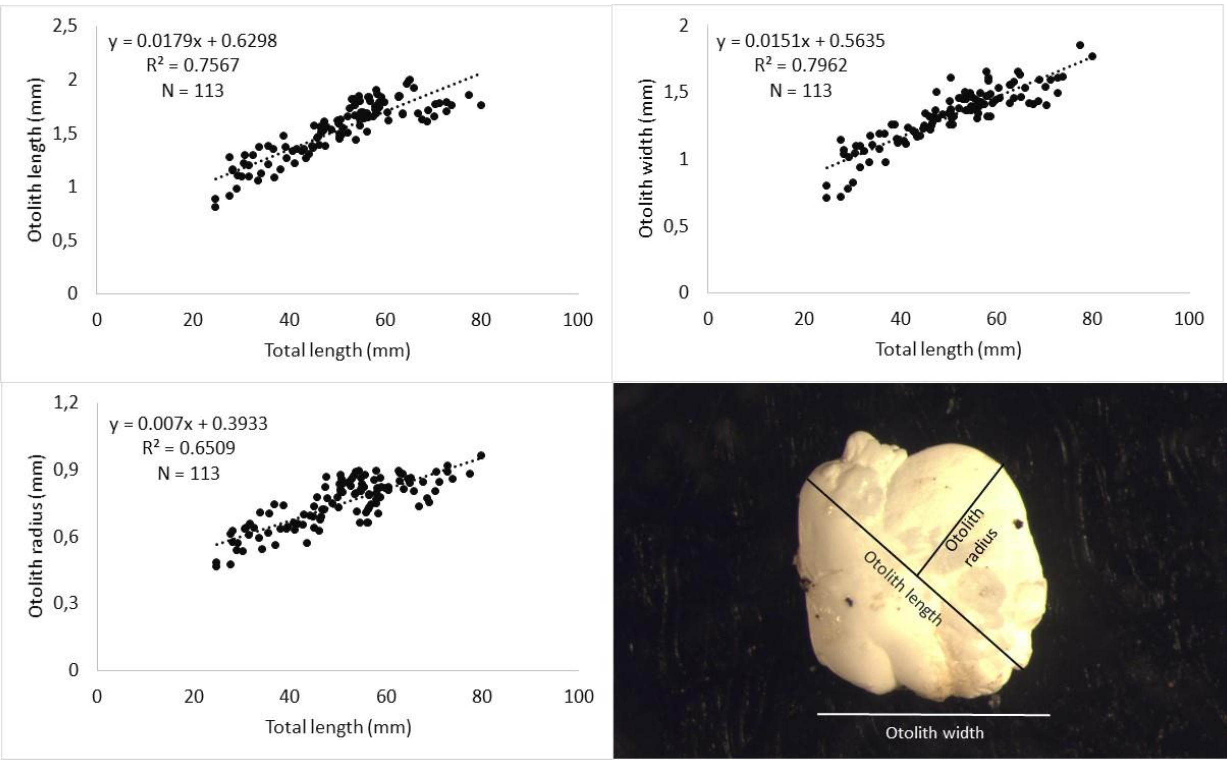

Figure 3. The relationships between TL-OL, TL-OW and TL-OR of *P. marmoratus*

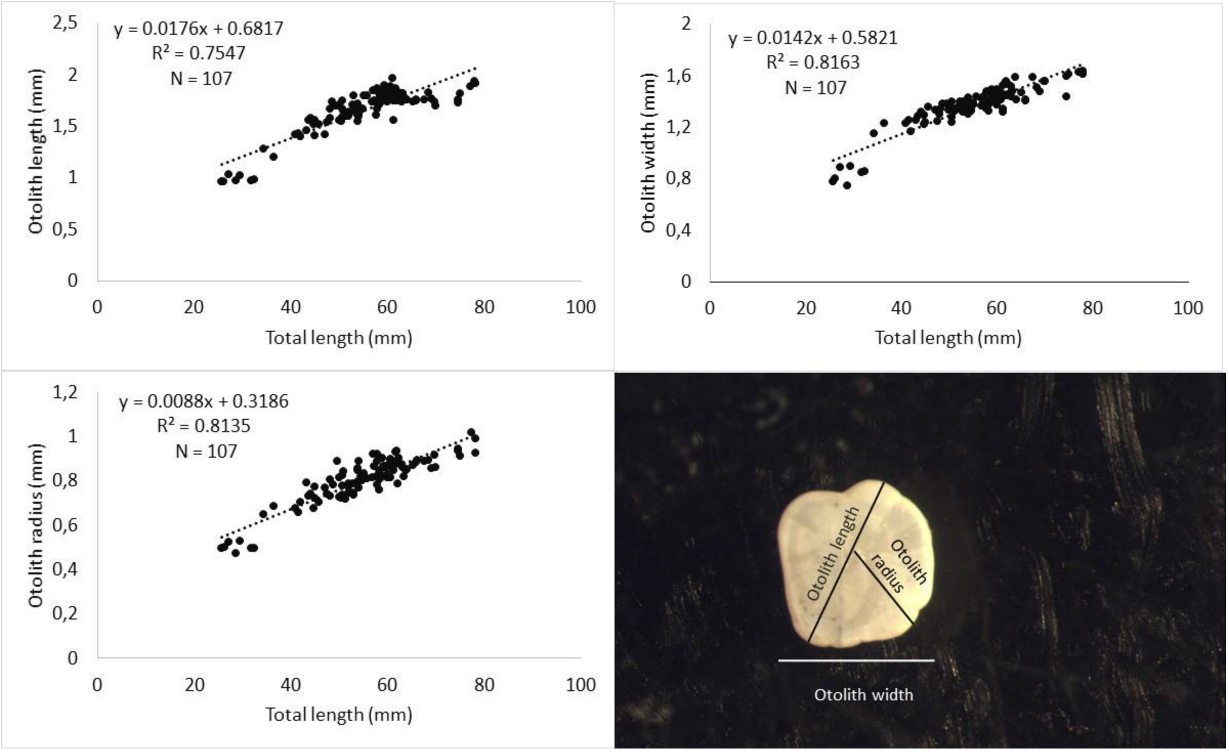

Figure 4. The relationships between TL-OL, TL-OW and TL-OR of *P. bathi*

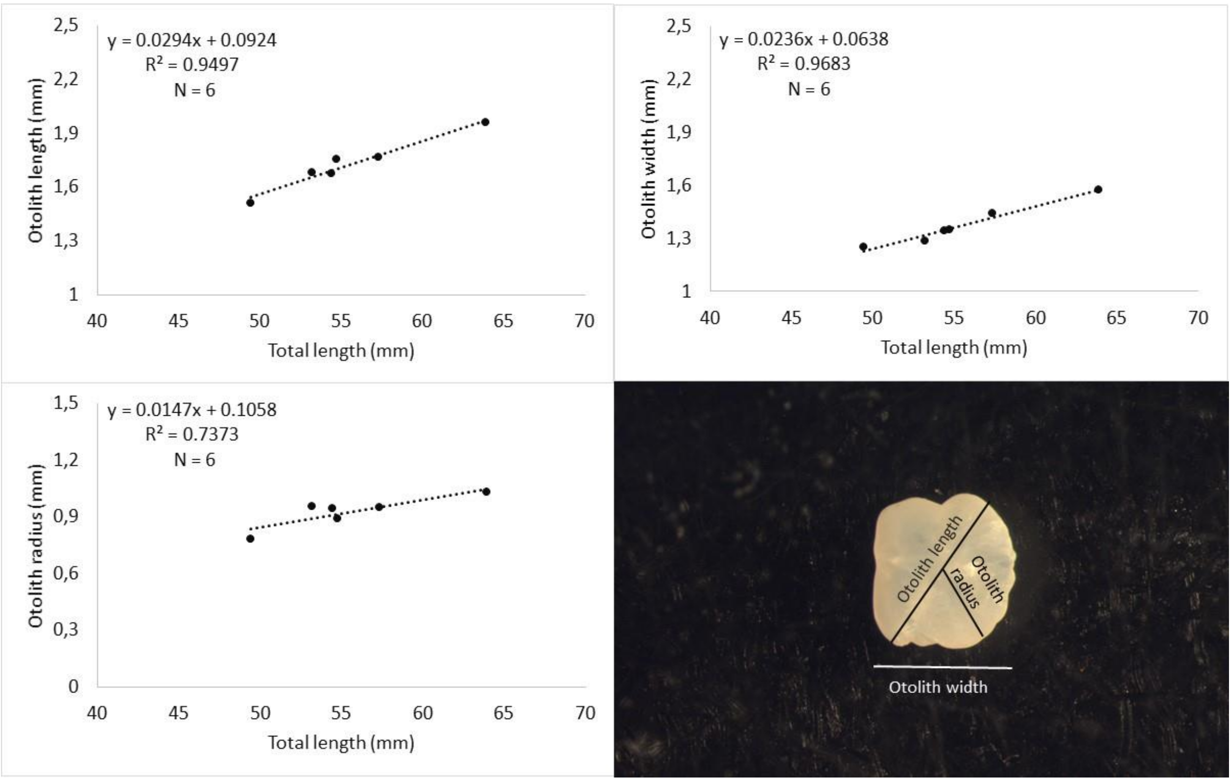

Figure 5. The relationships between TL-OL, TL-OW and TL-OR of *P. minutus*

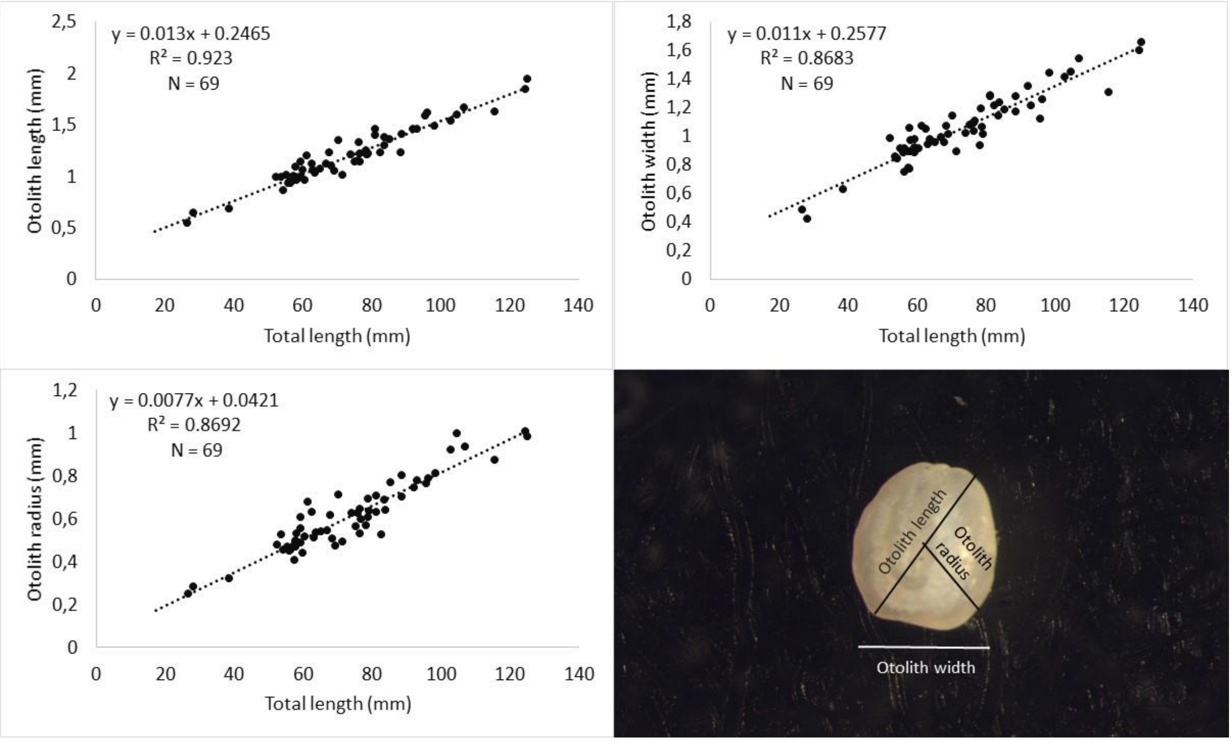

Figure 6. The relationships between TL-OL, TL-OW and TL-OR of *S. kleinii*

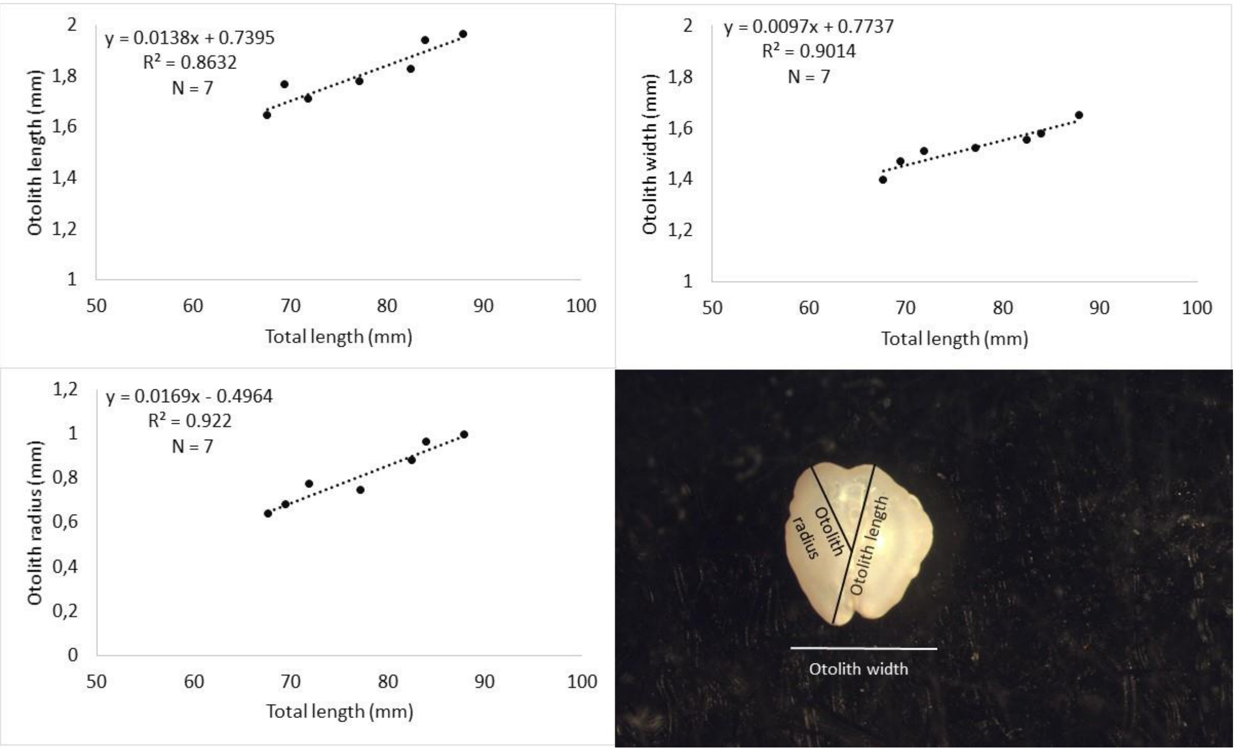

Figure 7. The relationships between TL-OL, TL-OW and TL-OR of *C. lucerna*

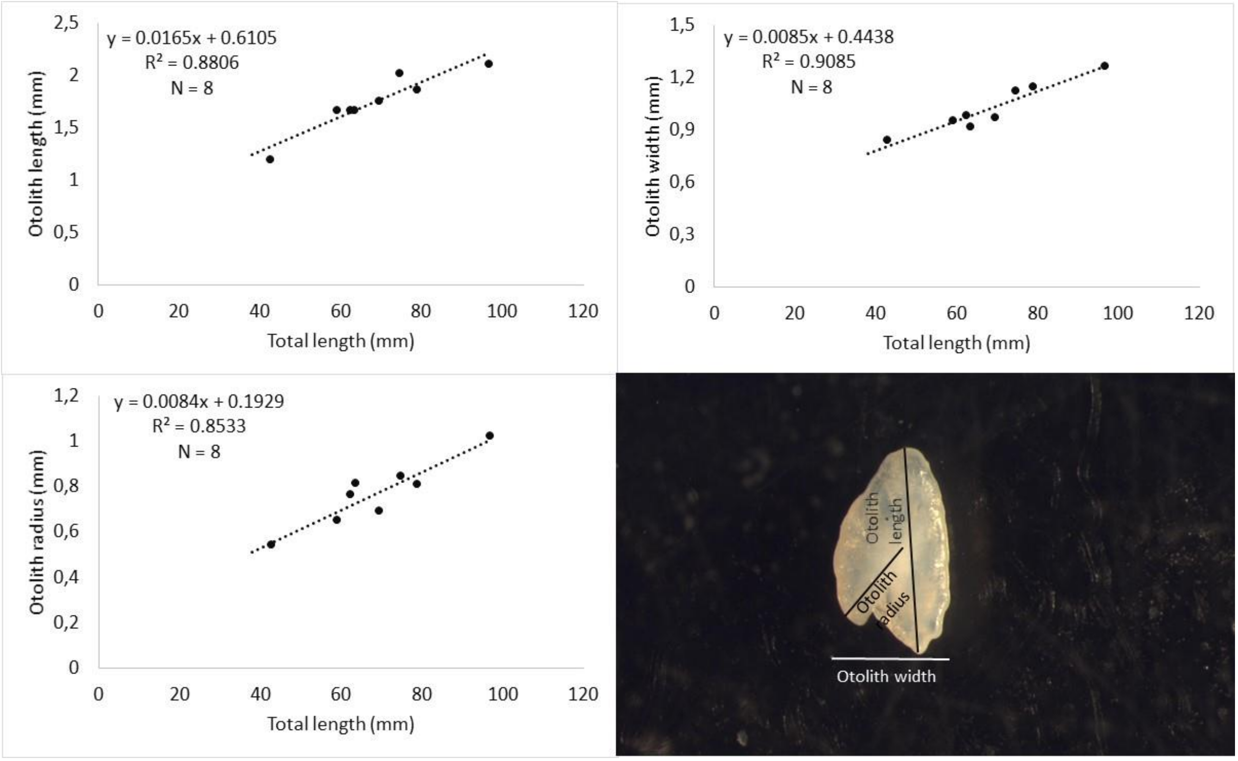

Figure 8. The relationships between TL-OL, TL-OW and TL-OR of *S. roissali*

4. Discussion

The newly settlers and juveniles of demersal fish species mostly disribute in shallower waters. Beside, some palegic juvenile shoals such as Sardines, Anchovies etc. can be seen in the coastal areas. In addition to these, small-sized adult fish species such as Gobiidae, Labridae etc. family members mostly distribute these areas to avoid larger predators. Thus, coastal areas constitute important growth and nursery areas for these species, and embodies important biodiversity (Sheaves et al., 2015). So, the commercial use of beach seine nets is forbidden in the Turkiye Seas. For scientific purposes, it can be used after permission from authorized institution. Hovewer, the most appropriate method to collect coastal fish species is known as beach seine sampling with the scientific purposes. Due to small sized adults and juveniles constitute the upper levels of the food chain, a great majority of the prey of carnivorous species arised from these species (Lukoschek and McCormick, 2001). The studies related to otolith sizes and shapes are valuable tools for stomach content analyses. Beside, otolith size-fish size relationships are important outputs for estimating fish size from the otolith size (Morley and Belchier, 2002; Hüssy et al., 2016; Więcaszek et al., 2020). These relationships give a chance to estimate prey size from otolith size and prey identification from otolith shape. Thus, seven small-sized aduly and juvenile fish species, which were dominant species of beach seine sampling were selected to reveal fish size-otolith size relationships in the present study.

The mean OL, OW, OR and TL of *P. marmoratus* were found to be 1.264 mm, 1.133 mm, 0.637 mm and 34 mm, respectively in Gökçeada Island, North Aegean Sea (Altin and Ayyildiz, 2018), which were smaller sizes than the results of the present study. But they determined higher coefficient of determination value for TL-OL, TL-OW, TL-OR of this species. The belief is that a beach seine net with specific mesh size is associated with effective catching larger individuals than specific size individuals. Conversely, Akyol and Kınacıgil (2001) compered to this study detected larger mean fork length (225.19 mm), OL (6.61 mm), and OW (3.35 mm) of *L. saliens* in the Aegean Sea. They did not calculate length-

length relationships. Whereas, Gümüş et al. (2001) found relatively the same sizes as 43 mm total length, 1.494 mm otolith length and 2.008 mm otolith width for *P. marmaratus* in the Black Sea. Although *P. marmoratus* was sampled from coastal areas in all areas, individuals were collected with varied fishing gear in the Aegean Sea and the sea water characteristics were relatively different from the Marmara Sea and the Black Sea. Also, L'Abée-Lund (1988) and Dawson (1991) emphasized that otoliths are used to differentiate stocks of the same species. Thus, it can be said that lots of variables such as the varied sea water characteristics, prey type, prey biomass, sampling gear type and season may be affected the varied mean sizes from the distinct geographical areas.

The OL, OW and OR measurements of the three *Pomatoschistus* species presented in this study were close to each other. Whereas, these otolith sizes of three species showed variations and these equations can be benefit for stomach content analyses when back-calculation of the size and species from the otolith. The TL-OL relationship of adult *C. lucerna* was estimated as y=0.1325x+0.9428 (R^2=0.686) in the Iskenderun Bay, Southeastern part of the Mediterranean Sea (Başusta and Bıyıklı, 2022). The parameters "a" and "b" in the equation were estimated as 0.0138 and 0.7395 in this study. Although the life phase and sampling location were relatively different between these two studies, the TL-OL relationship was found to be similar. Conversely, the TL-OW equation of these two studies showed great variations for *C. lucerna*.

Although four of the seven species were adults, the OL, OW and OR were close to each other. The three species were belong to the same genus, whereas the remaining species were belong to varied families. Thus, the primary factor affecting the otolith size of coastal species may be TL.

5. Conclusion

As a result of the seven fish species investigated for the first time the total length-otolith dimensions relationships in the Marmara Sea and *P. bathi P. minutus, S. kleinii, S.roissali* studied for the first time in the Turkiye Seas with this study. Also, otolith dimensions *P. bathi* contribute to the first results in the literature. This research provides new information because of the lack of data regarding the relationships between otolith dimensions and fish length for seven species. The fish length-otolith dimensions studies provide necessary information on species identification and size estimation of fish species in predator-prey studies. Also, these results are helpful for stock differentiation studies due to reveal detailed data.

Conflict of interest

The authors declare that there are no conflicts of interest or competing interests

Author contribution

The contribution of the authors to the present study is equal. All the authors read and approved the final manuscript.

Ethical approval

Ethics committee approval is not required.

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