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A Preliminary Study on Otolith-total Length Relationship of the Common Hake (*Merluccius merluccius* L., 1758) in İzmir Bay, Aegean Sea

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Abstract: This study presents the relationships of length-weight, age and otolith length-total length in *Merluccius merluccius*. The length and age of the 316 wild-caught specimens were compared with the length and age calculated theoretically, together with the results from the back-calculated lengths-at-age. Lengths of the specimens captured by bottom trawls ranged from 136 to 435 mm and their ages were estimated between one and seven. Six different groups of total length were designated and otolith lengths were compared with each of them. Similarly, the same parameters were utilized to determine sexual differences. As a result, it was observed that age and length groups of wild-caught specimens coincide with the age and length groups calculated theoretically. Evidently, each otolith length group conforming to total length groups were distributed homogeneously, whereas, the differences between them were significant statistically.

Key words: Length-weight, age, otolith length-total length, *Merluceius merluecius*

INTRODUCTION

Among demersal finfish groups, *Merluccius* species are one of the most heavily fished ones (Moralles-Nin, 1997). The European hake, *Merluccius merluccius* is a highly sought after species which is widely distributed from the Black Sea through the Straits of Gibraltar and along the Atlantic coast from Morocco to Norway (Svetovidov, 1986). The economic value of *M. merluccius* is relatively high, especially in Northern Mediterranean mixed fisheries (Alheit and Pitcher, 1995). Not only is the common hake one of the most commercially important fish species in the fishery of İzmir Bay, *M. merluccius* is also important for Turkish fisheries, considering its contribution to marine fish production in Turkey (9.734 of 453.123 t in 1993 and 7.500 of 416.126 t in 2003); (Anonymous, 1993). In the vicinity of Hekim Island, which is one of the most productive environments in İzmir Bay, *M. merluccius* is the second species (considering the quantity of catch) after the common bream, *Diplodus annularis* (Uçkun *et al*., 2000).

Knowledge of growth parameters is a must for any study on population dynamics. Information about otolith length-total length correlation has several practical benefits for the studies on both fish biology and population dynamic (Treacy and Crawford, 1981; Spratt, 1975; Echeveria, 1987; Hoşsucu *et al*., 1999). Otolith studies on the Turkish ichthyofauna are mostly on age determination, however, morphometric and morphologic studies on otolith are quite limited in number (Erman, 1961; Akkıran, 1984; Cihangir and Kaya, 1988; Hoşsucu *et al*., 1999). However, in spite of scarcely found a few studies on the biology of *M. merluccius*, (Kara and Kınacıgil, 1990; Uçkun *et al*., 2000), available literature has revealed the lack of otolith-total length relationship studies on the common hake in Turkey.

This study attempts to emphasize otolith-total length relationship of *M. merluccius* and measure growth zones in otoliths for back calculation of length-at-age from otolith as validation method. Considering the species' commercially importance, the present survey in Izmir Bay may be applied to fisheries management, or at least will be of practical use.

MATERIALS AND METHODS

The Research Vessel Hippocampus owned by Faculty of Fisheries, Ege University, has been used to collect the specimens. A total of 336 *M. merluccius* specimens was caught seasonally over a year between April 1994 and March 1995, by using the bottom trawls (on sandy and muddy bottoms at a depth of 40-45 m around Hekim and Uzun islands) in İzmir Bay (Fig. 1).

Total length and total weight of specimens caught were measured to the nearest 1 mm (total length, TL) and weighted to the nearest 0.01 g (total weight, W), respectively, in the research vessel and the laboratory. Specimens' otoliths were removed immediately and stored dry in properly labeled envelopes.

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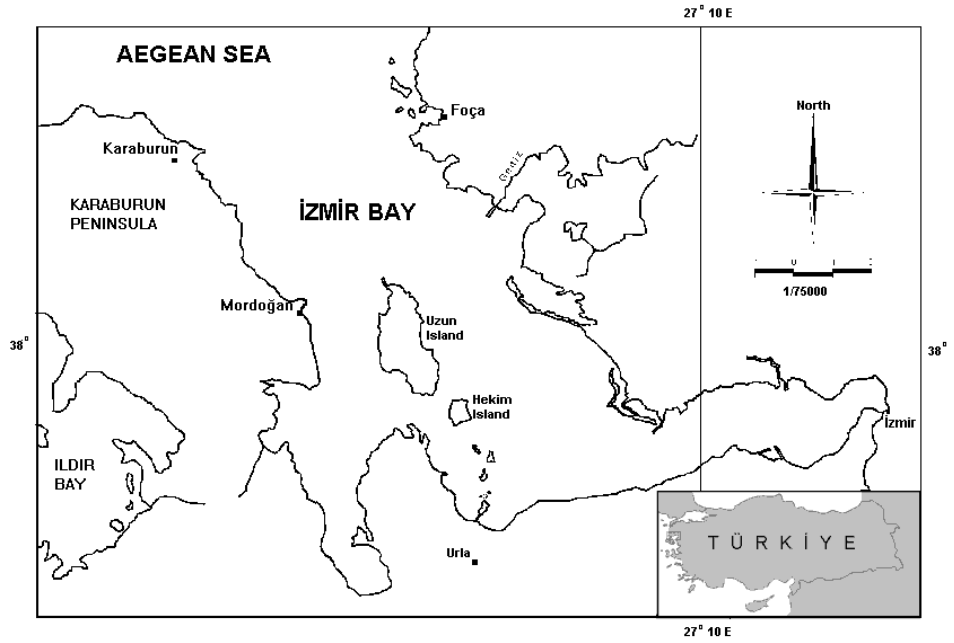

Fig. 1: Map of İzmir Bay where the specimens were collected

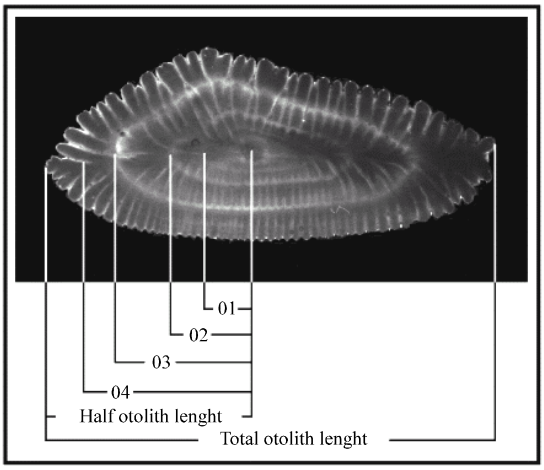

Fig. 2: A *Merluccius merluccius* otolith with key to measurements

The maximum, straight line lengths of the otolith samples were measured to the nearest 0.01 mm from the anterior tip to the posteriormost projection (Fig. 2). Thick otoliths were made thin with wetted sandpaper, while small ones immediately became transparent in 70% alcohol. For larger and opaque ones, the immersion in a glycerin-water solution (1:1) for a minimum of 24 h (Maximum 48 h) cleared the otolith sufficiently for examination. Otoliths prepared in those ways and then mounted on a black background were examined by three readers under reflected light with a stereo microscope having micrometer eye-piece.

Ages were determined according to method given by Chugunova (1963). For corroboration, three authors checked the number of opaque zones and presence of marginal translucent zone. The results were compared, critical readings discarded and thus a total of 316 otoliths was taken into consideration for analyses. Two different axis measurements (i.e., long axis and short axis) were taken because of elliptical shape of the *Merluccius merluccius* otoliths. The short axis measurements were discarded since this axis was less proportional to the body growth than the long axis (i.e., r^2 was 86.63 for long axis while it is 51.76 for short axis). Thus, we considered the long axis for further analyses.

Growth was expressed in terms of the von Bertalanffy equation (von Bertalanffy 1957; Pauly 1979; Sparre and Venema 1998);

$L_t = L_\infty [1-\exp^{-k(t-to)}]$ where L_t is length at age t, L_∞ is maximum asymptotic length, k is growth curvature parameter, t_0 is computed age at length and weight equal to zero. The length-weight relationship is defined as: $W = aL^b$ (Gulland's equation; Gulland, 1969) where W is total body weight (g), L is total length (cm) and a and b are constants.

We used Ricker (1973) method for analysis of the linear regression of otolith length on total length. The Fraser-Lee equation [$L_a = d+(L_c-d)O_c^{-1}O_a$ with L_c and O_c the fish length and otolith size at capture, respectively, d the intercept of the regression, O_a the otolith size at a previous age (a); in Stevenson and Campana (1992)] was utilized to determine the body-otolith relationship and the growth history of the fish. The distances from nuclear

area to the opaque zones were measured consistently from the same morphological position and direction.

The significant difference of the otolith length groups against the total length groups was calculated with one-way analyses of variance (ANOVA) and Multiple range analyses (for between groups and within groups), respectively. In addition, we tried a Kolmogorov-Smirnov test (K-S) for testing distribution between males and females, using the Statgraph program (version 6.0).

RESULTS AND DISCUSSION

The age and/or size of a fish can be estimated from its otolith as obtained from a predator's stomach, from a core or dredge sampling, or even from a fossil (Treacy and Crawford, 1981). A determined relationship between otolith length and total length in a species enable researchers to estimate the total length of a fish from its otolith length, or vice versa (Fitch and Brownell, 1968; Spratt, 1975; Echeveria, 1987).

Kolmogorow-Smirnov Two-Sample Test, which determines whether two samples come from the same distribution, showed that there were no difference between the distributions of total length values of female and male (for length; DN: 0.214, K-S: 1.730, Sig. Level: 0.005). Thus, male and female specimens were pooled for further analyses. Length frequency distribution of the pooled data showed that specimens were relatively more abundant in length classes ranged from 26-32 cm (Fig. 3). Utilizing the total length values of the specimens in all age groups (Fig. 4), the von Bertalanffy's growth equations were computed as $L_{\infty}= 894.55(1-e^{-0.074(t+1.229)})$ for overall specimens.

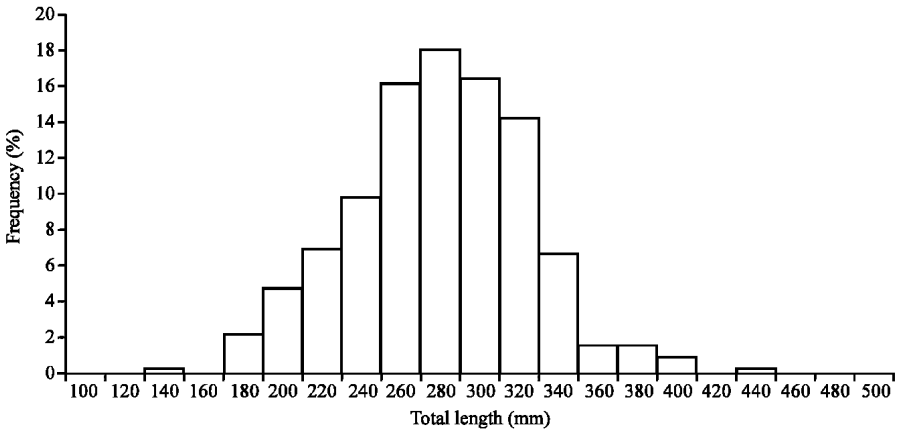

Fig. 3: Frequency analysis of total length in *M. merluccius*

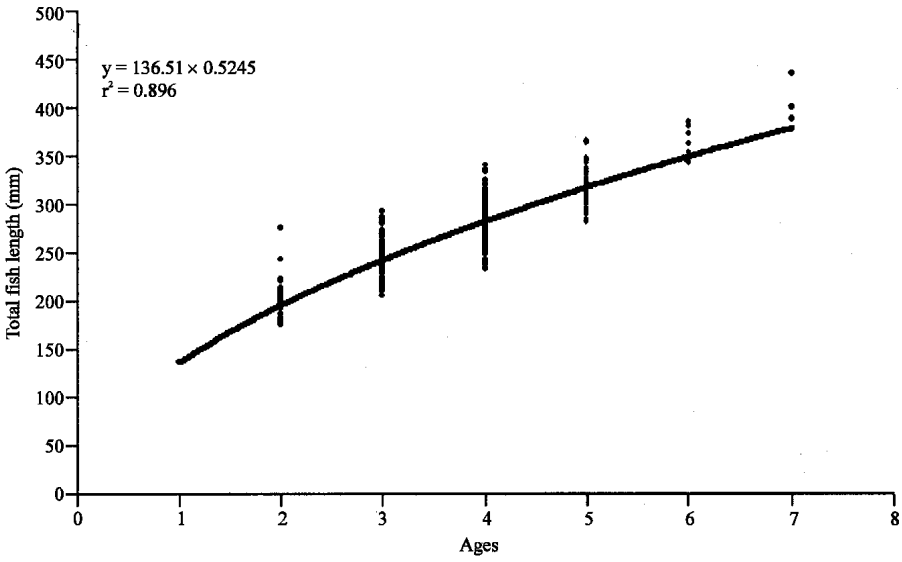

Fig. 4: Total length in *M. merluccius*

Table 1: Results of One-way ANOVA variance analysis of the total length groups in *M. merluccius* (*Highest significant difference)

Total length groups	N	Average	Std. error (internal)	Std. Error (pooled s)	95% Tukey intervals for mean	HSD*
1	9	173.22	4.70	4.77	166.58	179.87
2	52	211.46	2.06	1.98	208.70	214.23
3	134	260.67	1.20	1.24	258.95	262.39
4	105	306.50	1.38	1.40	304.56	308.45
5	13	356.62	4.45	3.97	351.09	362.14
6	3	407.67	14.10	8.27	396.16	419.17
Total	316	270.66	0.81	0.81	269.53	271.78
Source of variance		Sum of squarer	df	Mean square	F-ratio	Sig. level
Between groups		568317.38	5.00	113663.48	554.12	0.000
Within groups		63558.02	310.00	205.12	-	-

Table 2: Results of One-way ANOVA variance analysis of the otolith length groups vs. total length groups in *M. merluccius* (*Highest significant difference)

Otolith length groups	N	Average	Std. Error (internal)	Std. Error (pooled s)	95% Tukey Intervals for mean	HSD*
1	9	8.01	0.30	0.32	7.56	8.46
2	52	10.04	0.16	0.14	9.85	10.23
3	134	11.90	0.07	0.08	11.79	12.02
4	105	13.76	0.09	0.10	13.62	13.89
5	13	15.95	0.44	0.27	15.58	16.33
6	3	18.53	0.49	0.56	17.75	19.32
Total	316	12.33	0.05	0.05	12.26	12.41
Source of variance		Sum of squares	df	Mean square	F-ratio	Sig. level
Between groups		964.93	5	192.99	203.52	0.000
Within groups		293.95	310	0.95	-	-

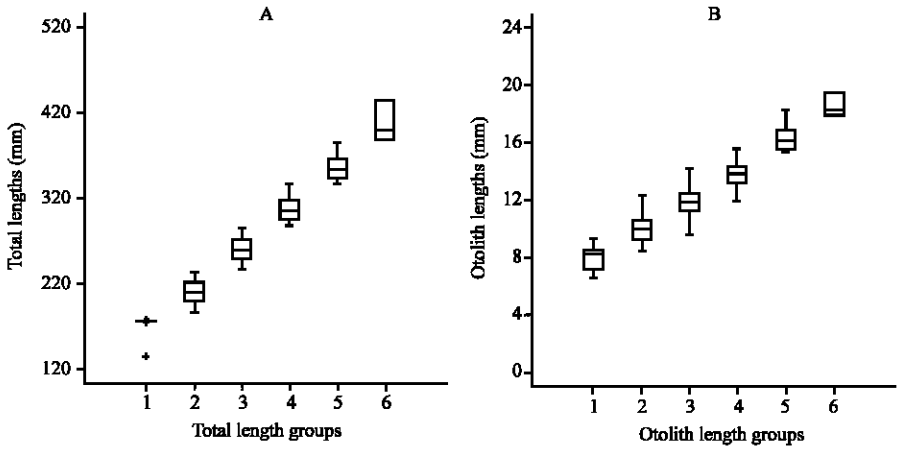

Fig. 5: Comparisons of total length groups (A) and otolith length groups (B) in *M. merluccius* (Tukey one-way ANOVA analysis; $F_{(5, 310)} = 554.12$ for total length groups and $F_{(5, 310)} = 203.52$ for otolith length groups and $p<0.0001$ for both)

When age composition was examined, age-group IV (42.41%) is the most abundant group among 316 *M. merluccius* specimens, followed by III (26.27%), V (16.77%), II (11.39%), VI (1.90%) and VII (0.95%). Age-group I was represented by a single specimen (0.32%).

In order to analyze statistically the otolith lengths vs. the length groups, the sample was divided into size categories. Considering frequency analysis of total length and owing to the small sub-sample size for some categories, the data were merged into 50 mm length categories, giving six groups of total length for this analysis. These length groups are, respectively: first group (<186 mm), second group (186-235 mm), third group (236-285 mm), fourth group (286-335 mm), fifth group (336-385 mm) and sixth group (>386 mm). One-way ANOVA computing significant differences in within total length group and between total length groups showed that each total length group had a homogeneous dispersion in its own group but statistical differences between length groups (Table 1 and Fig. 5A). Similarly, when otolith length groups vs. total length groups were analyzed with same test, it was seen that each otolith group had a homogeneous dispersion in its own group, whereas the difference between otolith groups was significant statistically (Table 2 and Fig. 5B). As shown

Table 3: Statistically significant pairwise differences (asterisk) among the total length groups (Group 1 = <186 mm, 2 = 185-235 mm, 3 = 236-285 mm, 4 = 286-335 mm, 5 = 336-385 mm and 6 = >386 mm) and the otolith length groups (*Denotes a significant difference)

Total length groups			Otolith length groups		
Groups	Difference	± Limits	Groups	Difference	± Limits
1 - 2*	-38.24	10.18	1-2*	-2.03	0.69
1 - 3*	-87.45	9.71	1-3*	-3.89	0.66
1 - 4*	-133.28	9.79	1-4*	-5.75	0.67
1 - 5*	-183.39	12.22	1-5*	-7.94	0.83
1 - 6*	-234.44	18.79	1-6*	-10.52	1.28
2 - 3*	-49.21	4.61	2-3*	-1.86	0.31
2 - 4*	-95.04	4.78	2-4*	-3.72	0.32
2 - 5*	-145.15	8.74	2-5*	-5.91	0.59
2 - 6*	-196.21	16.74	2-6*	-8.49	1.14
3 - 4*	-45.83	3.67	3-4*	-1.85	0.25
3 - 5*	-95.94	8.19	3-5*	-4.05	0.56
3 - 6*	-146.99	16.46	3-6*	-6.33	1.12
4 - 5*	-50.11	8.29	4-5*	-2.20	0.56
4 - 6*	-101.16	16.50	4-6*	-4.78	1.12
5 - 6*	-51.05	18.05	5-6*	-2.58	1.23

Table 4: Average body lengths (mm) at each age group through back calculation (N- number of specimens; L- body length)

Age	N	L1	L2	L3	L4	L5	L6	L7
I	1	131.99						
II	36	132.06	199.53					
III	83	133.99	190.16	249.29				
IV	134	129.13	185.16	234.69	283.37			
V	53	134.74	184.62	227.39	285.92	333.20		
VI	6	133.39	185.69	234.27	270.32	312.65	365.39	
VII	3	114.82	185.99	230.23	272.93	294.22	362.94	401.10
Total	316							
Average	Back calculated	130.02	188.53	235.18	278.13	313.36	364.17	401.10
	Caught in nature	136.00	198.56	244.28	281.45	317.64	366.00	407.67
	von Bertallany	135.49	189.42	239.42	286.06	329.29	369.45	406.76

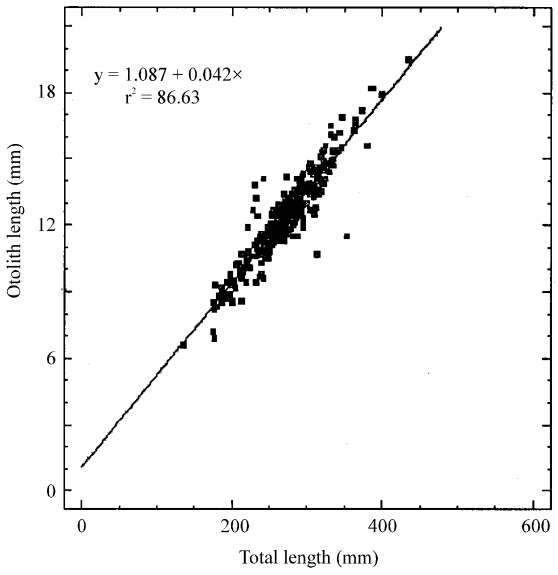

Fig. 6: Regression analysis between total fish length and otolith length in *M. merluccius*

in Fig. 5 A and B, there were no data found outside of the maximum and minimum values in both total length groups and otolith groups vs. total length groups. As shown in Table 3, the differences between the groups compared with each other are statistically significant.

The otolith morphology is an additional characteristic among these species-specific criteria, as used here for *M. merluccius*. The age determination of European hake is difficult because of numerous false rings and complex nuclear ring patterns and no common interpretation criteria can be applied to otoliths (Oliver *et al*., 1989; Moralles-Nin, 1997). Using the allometric relationship between otolith growth and overall body growth, one can determine the length of a wild-caught fish from its otolith (Fitch and Brownell, 1968; Spratt, 1975; Echeveria, 1987; Hoşsucu *et al*., 1999). From a linear-regression analysis for otolith-fish length relationship of the specimens combined, the smallest fish (136 mm) was set to match with an otolith length of 6.6 mm and the longest fish (435 mm) to match an otolith length of 19.5 mm (Fig. 6). As seen in Fig. 6, otolith lengths vs. fish lengths of the 250-350 mm size class were more abundant in the range between 11.0-16.0 mm. The relationship between body length and the otolith measurement of *M. merluccius* specimens from İzmir Bay was linear but not directly proportional and the line crossed the ordinate at a positive length. Thus, according to the Fraser-Lee equation ($L_a=d+(L_c-d)O_c^{-1}O_a$), the back-calculated lengths at ages were given in Table 4. As shown in Table 4, the average body lengths calculated for age group I (130.02 mm), II (188.53 mm), III (235.18 mm), IV (278.13 mm),

V (313.36 mm), VI (364.17 mm) and VII (401.10 mm) respectively, coincide with the wild-caught age groups and the age groups calculated theoretically according to the von Bertalanffy equation [for age group I (135.49 mm), II (189.42 mm), III (239.52 mm), IV (286.06 mm), V (329.29 mm), VI (369.45 mm) and VII (406.76 mm)]. Utilizing the back-calculated length values of the specimens in all age groups, the von Bertalanffy's growth equations were computed as $L_{\infty} = 894.55(1-e^{-0.074(t+1.229)})$ for overall specimens. Colloca *et al*. (2003), who studied growth parameters in European hake of the central Mediterranean sea, computed $L_{\infty} = 93.2$ ($k = 0.13$; $t_0 = -0.35$) and $L_{\infty} = 45.7$ ($k = 0.40$; $t_0 = -0.1$) for females and males, respectively for a total of 689 otoliths. The average body lengths calculated by authors are as fallows: age group I (14.69 cm), II (26.30 cm), III (34.90 cm), IV (40.08 cm), V (45.91 cm), VI (51.12 cm), VII (55.60 cm), VIII (60.80), IX (65.99 cm), X (68.87 cm), XI (72.90 cm), XII (73.20 cm), XIII (76.50), XIV (79.40 cm), XV (84.80 cm) and XVI (87.50 cm). Consequently, the estimated ages for the specimens caught in nature are quite similar to the ages computed in back calculation and von Bertalanffy.

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