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New Fisheries-related data from the Mediterranean Sea (November, 2016)

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Abstract

In this fourth Collective Article, with fisheries-related data from the Mediterranean, we present weight-length relationships for seven deep-sea fish species (*Brama brama, Conger conger, Etmopterus spinax, Molva macrophthalma, Mora moro, Pagellus bogaraveo, Phycis blennoides*) from the Eastern Ionian Sea; *Scyliorhinus canicula* from various locations in the Mediterranean Sea and weight-length relationships and condition factor of five Mugilidae species (*Liza aurata, Liza saliens, Liza ramada, Mugil cephalus, Chelon labrosus*) from a Mediterranean lagoon in the Ionian Sea. Moreover, we present otolith weight, fish length and otolith length relationships of the red mullet (*Mullus barbatus*) in the Aegean and Ionian Sea and otolith weight relationships in European hake (*Merluccius merluccius*) from the Greek Seas.

Keywords: Weight-length relationships, otolith-weight relationships, condition factor, Aegean Sea, Ionian Sea.

Introduction

It is well-known that fish biology/ecology information (e.g. morphometrics, weight-length relationships, condition factor, age, growth, reproduction, food and feeding habits, mortality) is of outmost importance for fish and fisheries biology and ecology not only to fill the gaps in the academic knowledge but also for efficient fisheries management. Environmental factors may an affect the biological parameters of fish stocks in a number of ways (e.g. recruitment, size at maturity, growth, catchability). Furthermore, many biological parameters are known to vary over small geographical ranges (Amstrong *et al.,* 2004; Gerritsen *et al.,* 2006) or different time periods (Morgan, 2008); this information could be useful for a better understanding of the role and response of species to changing ecosystems and should be taken into account in order to improve fisheries management. Mediterranean Marine Science is continuing the successful publishing of fisheries-related data through its Collective Articles.

In this collective article, we present weight-length relationships for seven deep-sea fish species (*Brama brama, Conger conger, Etmopterus spinax, Molva macrophthalma, Mora moro, Pagellus bogaraveo, Phycis blennoides*) from the Eastern Ionian Sea and for the small-spotted catshark (*Scyliorhinus canicula*) from various locations in the Mediterranean Sea as well as weight-length relationships and condition factor of five Mugilidae species (*Liza aurata, Liza saliens, Liza ramada, Mugil cephalus, Chelon labrosus*) from a Mediterranean lagoon in the Ionian Sea. We also present otolith weight, fish length and otolith length relationships of the red mullet (*Mullus barbatus*) in the Aegean and Ionian Sea and otolith weight relationships in European hake (*Merluccius merluccius*) from the Greek Seas.

1. Weight-length relationships for eight deep-sea fish species from the Eastern Ionian Sea, Greece

A. Anastasopoulou and Ch. Mytilineou

Weight-length relationships (WLR) are important in fish and fisheries biology and fisheries management. In this study, weight-length relationships were estimated for seven deep-sea fish species in the Eastern Ionian Sea. Samples were collected from two experimental bottom trawl (1999-2001) and two longline (2010) surveys conducted at depths ranging between 300 and 1200 meters. Fish were measured for total length (*TL*) to the nearest 0.1cm and weighted (Total body weight, *TW*) to the nearest g. Estimation of the WLR was made by the adjustment of an exponential curve ($W = aL^b$) converted into its logarithmic expression ($\ln W = \ln a + b\ln TL$), where *W* is the *TW*, *L* is *TL*, *a* is the intercept and *b* the slope. Student's t-test was used to test the isometric growth (null hypothesis $H_o = 3$).

A total of 728 individuals of seven species were studied. The species, number of specimens, size range, WLR parameters *a* and *b*, determination coefficient (R^2) and growth type (isometric or allometric) are shown in Table 1. All R^2 values were greater than 0.97 and only the R^2 of *Molva macrophthalma* was 0.92. All regressions were highly significant ($P < 0.001$). The sample size for species varied from 11 specimens for *Brama brama* to 321 for *Pagellus bogaraveo*. The values of the allometric coefficient (*b*) ranged from 2.92 for *P. bogaraveo* to 3.42 for *Conger conger*. Five species (71.4%) showed positive allometries ($b > 3$; t-test; $P < 0.001$); one species (14.3%)

negative allometry ($b < 3$; t-test; $P < 0.001$). Growth was found to be isometric ($b = 3$; t-test; $P > 0.005$) (Table 1) for *Molva macrophthalma* only.

For six species (*Pagellus bogaraveo, Phycis blennoides, Etmopterus spinax, Mora moro, Brama brama* and *Conger conger*) the b values of the weight-length relationship presented here were similar with those reported by other authors (e.g. Chilari *et al.,* 2006; Ferreira *et al.,* 2008; Ismen *et al.,* 2009; Morey *et al.,* 2003). Differences in b for the same species could be attributed to one or more factors: different geographical locations with specific environmental conditions, age, stage of maturity, sex, food availability, sampling (e.g. differences in length ranges, number of specimens, gear selectivity) and depth (Ricker, 1975).

Table 1. Length range (total length) and weight-length relationship parameters for eight deep-sea fish species from the E. Ionian Sea (n, sample size; a and b, relationship parameters; $Se_{(b)}$, standard error of b; R^2, coefficient of determination; Growth= +A, positive allometry; -A, negative allometry; I, isometry.

Species	n	Length range (cm)	a	b	$Se_{(b)}$	R^2	Growth
Pagellus bogaraveo	231	11.9-43.7	0.019	2.92	0.031	0.97	-A
Phycis blennoides	112	10.4-55.3	0.003	3.24	0.032	0.99	+A
Etmopterus spinax	205	10.0-39.3	0.003	3.12	0.023	0.99	+A
Mora moro	84	10.0-54.2	0.003	3.30	0.031	0.99	+A
Molva macrophthalma	19	45.2-74.1	0.002	3.08	0.214	0.92	I
Brama brama	11	31.5-64.3	0.006	3.20	0.096	0.99	+A
Conger conger	66	47.2-148.0	0.0003	3.42	0.081	0.97	+A

2. Weight-length relationships for the small-spotted catshark *Scyliorhinus canicula* (L. 1758) in the Mediterranean Sea

V. Kousteni, B. Guijarro and F. Hemida

Weight-length relationships (WLR) have important implications for fisheries science and population dynamics, allowing conversion of lengths into biomass, determining fish condition and comparing fish growth among areas (Froese *et al.,* 2011). In this study, WLR were established for the small-spotted catshark, *Scyliorhinus canicula* (Linnaeus, 1758) in various locations in the Mediterranean Sea. This species tends to form distinct stocks on a small spatial scale (e.g. Kousteni *et al.,* 2015), and thus the description of its WLR is fundamental even regionally.

A total of 1671 individuals were incidentally captured by bottom trawlers across the Mediterranean Sea [EMED: eastern Mediterranean: (SKY, Skyros Isl.; PSA, Psara Isl., KYK, Kyklades Isls - Aegean Sea; CRE - Cretan Sea), CMED: central Mediterranean Sea (PAR, Parga; KOR, Korinthiakos Gulf - Greek Ionian Sea) and WMED: western Mediterranean Sea (ALG, off Algeria; BAL, Balearic Isls)] between May 2008 and June 2012. Detailed information on the sampling procedure is given in Kousteni (2015). Total length (L_T) was measured to the nearest millimetre (mm) and total weight (W_T) was recorded to the nearest gram (g). Regression analysis was used to estimate WLR parameters. Student's *t*-test was used to identify the type of growth. The WLR slopes were compared for between-area differences by performing an analysis of covariance (ANCOVA).

The L_T of the sampled individuals lies within the previously reported *S. canicula* size range in the Mediterranean Sea (Kousteni, 2015 and references therein). All R^2 values of the WLR were equal to or greater than 0.90 and all regressions were highly significant (P<0.001). The values of the slope *(b)* ranged between 3.02 in CRE to 3.33 in SKY and KYK. For all sampling locations, except CRE and ALG, the slope *(b)* was significantly different from 3 (P_t<0.05) showing positive allometric growth (Table 2).

Table 2. Total length range and parameters of the WLR for *Scyliorhinus canicula* in the Mediterranean Sea (SKY, Skyros Isl.; PSA, Psara Isl., KYK, Kyklades Isls; CRE, Cretan Sea; KOR, Korinthiakos Gulf; PAR, Parga; ALG, off Algeria; BAL, Balearic Isls). P_t corresponds to the *P*-values of the applied Student's t-test.

Area	N	L_T range	α	b	$S.E._{(b)}$	R^2	P_t	Growth type
Eastern Mediterranean Sea								
SKY (Aegean Sea)	759	116–499	5E-07	3.33	0.010	0.99	0.0000 (t=31.9774)	Allometry+
PSA (Aegean Sea)	255	98–491	7E-07	3.25	0.018	0.99	5E-07 (t=14.40)	Allometry+
KYK (Aegean Sea)	204	89–517	4E-07	3.33	0.018	0.99	0.0000 (t=18.5439)	Allometry+
CRE (Cretan Sea)	104	304–486	3E-06	3.02	0.092	0.91	0.7989 (t=0.2554)	Isometry
Central Mediterranean Sea								
COR (Greek Ionian Sea)	47	151–487	1E-06	3.15	0.053	0.99	0.0067 (t=2.8350)	Allometry+
ION (Greek Ionian Sea)	90	300–492	7E-07	3.26	0.116	0.90	0.0286 (t=2.2243)	Allometry+
Western Mediterranean Sea								
ALG (Cap Djinet and Dellys)	74	300–550	2.E-6	3.10	0.117	0.91	0.4055 (t=0.8366)	Isometry
BAL (Balearic Sea)	138	116–505	1E-06	3.17	0.024	0.99	4E-11 (t=7.1607)	Allometry+

No significant difference was found in *(b)* between the CMED and the WMED samples (P_{ANCOVA}=0.5532, F=0.35). On the contrary, a significant difference was found in *(b)* values between the EMED and both the CMED (P_{ANCOVA}=0, F=18.01) and the WMED samples (P_{ANCOVA}=0, F=23.89). Thus, the differentiation of the *(b)* coefficient between the WMED and the EMED-CMED group (P_{ANCOVA}=0, F=20.40) could be attributed to the significant deviation of the *(b)* value of the EMED sample, showing an intermediate position of CMED between EMED and WMED (Fig. 1). These results were merely confirmed by genetic analyses (Kousteni *et al.,* 2015).

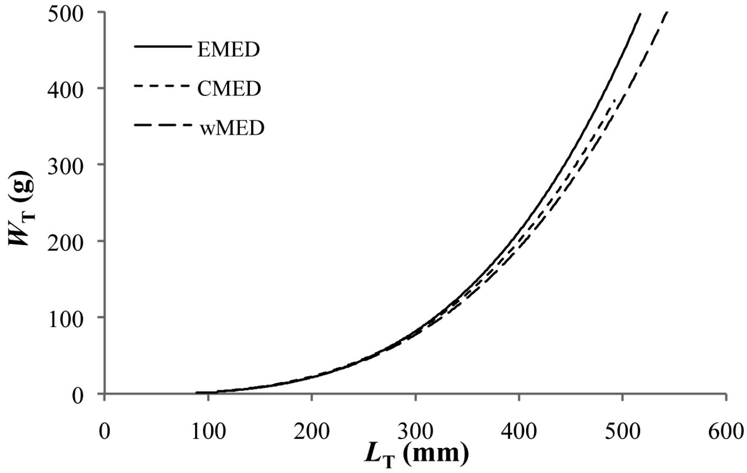


Fig. 1: WLR for *Scyliorhinus canicula* in the EMED (SKY, PSA, KYK and CRE), CMED (KOR and PAR) and WMED (ALG and BAL).

3. Weight-length relationship and condition factor of five *Mugilidae* species from a Mediterranean lagoon (Ionian Sea, Southern Italy)

E. Prato and F. Biandolino

In fisheries biology, weight-length relationships (WLRs) are useful to estimate the condition of fish and allow comparisons between fish species and populations from different habitats (Froese, 2006).

The family Mugilidae represents an important economic resource in several parts of the world, particularly in Mediterranean countries.

This study provides, for the first time, information on WLRs and the condition index of 5 commercial Mugilidae: *Liza aurata*, *L. saliens*, *L. ramada*, *Mugil cephalus* and *Chelon labrosus* inhabiting an important fishery basin of southern Italy (Ionian Sea, Central Mediterranean), during four seasons.

A survey was conducted from March 2008 to April 2009 in Mar Piccolo (40° 28' N; 17° 15' E), a semi-enclosed basin located in the North of the Gulf of Taranto. The individuals were collected using 2 mm mesh fyke nets and measured for total length (TL) and body weight (W). The WLRs was calculated using the exponential regression equation $W=aL^b$. Student's t-test was applied to test for variance of the mean *b* value from 3 at the 0.05 significance level. Fulton's condition factor was calculated from the relationship between the weight of a fish and its length, to describe the "condition" of the fish (Froese, 2006).

In this study, a total of 1241 individuals were caught. *Liza aurata,* with 944 individuals, was the dominant species followed by *L. saliens* (178). Sample size, range of TL (cm) and W (g), WLR parameters and statistics for each Mugilidae species in each season are presented in Table 3. For *L. ramada* and *Mugil cephalus,* in some seasons, only a few specimens were found and thus, despite their high R^2 values, their WLRs should be treated with caution (Karakulak *et al.,* 2006). The high statistical significance of R^2 attested a strong correlation between the length and weight of these Mugilidae species. Values of '*b*' ranged between 2.10 (*M. cephalus* in spring) and 3.2 (*L. ramada* in summer). Most Mugilidae displayed isometric ($b=3$; $p>0.05$) and negative allometric growth ($b<3$; $p<0.05$) (Table 3). Extremely high or low *b* values may be due to small sample size and limited length ranges (Froese, 2006).

Fulton's condition factor (K) ranged from 0.70 ± 0.20 (*L. ramada* in winter) to 1.08 ± 0.18 (*L. saliens* in spring). The lowest mean K factor was recorded in the winter.

The comparison of our findings against estimates from other areas showed that the WLR parameters of this study were within the ranges reported in the literature (Koutrakis and Tsikliras, 2003; Gündoğdu *et al.,* 2016). These new data provide useful basic biological information on 5 indigenous fishes from this Mediterranean area that could be valuable for fishery biologists and for decision-making pertaining to regulations for sustainable fishery management and conservation of fish stocks.

Table 3. Descriptive statistics and estimated parameters of weight-length relationships of five Mugilidae species caught in the Mar Piccolo Sea (Ionian sea, Central Mediterranean). N = sample size; TL: Total Length (cm); W: Weight (g); a = Intercept; b = Slope; S.E. (b)= Standard Error of b; R^2 = Coefficient of Determination; K = Condition index.

Species	Common names	Season	N°	TL range (cm)	W range (g)	W=aTL^b				Growth (t-test)	K
						a	*b*	S.E. (b)	R^2		
Liza aurata	Glolden grey mullet	Spring	217	4.5 - 22.0	1.12-100.0	0.026	2.74	0.18	0.94	b=3	0.85±0.12
		Summer	321	4.5 - 22.0	1.15-100.0	0.012	2.85	0.09	0.97	b<3	0.89±0.02
		Autumn	233	4.5 - 22.0	0.82-100.0	0.011	2.93	0.07	0.94	b=3	0.89±0.07
		Winter	173	13.0 - 22.0	15.1-101.3	0.057	2.30	0.11	0.70	b<3	0.75±0.04
Liza saliens	Leaping grey mullet	Spring	69	4.0 - 22.0	1.02-76.3	0.057	2.30	0.09	0.94	b<3	1.08±0.18
		Summer	50	6.0 - 22.0	0.98-95.5	0.006	3.13	0.31	0.96	b=3	0.90±0.10
		Autumn	11	5.4 - 18.0	1.51-55.6	0.005	2.49	0.37	0.98	b=3	0.88±0.10
		Winter	48	13.0 - 22.0	30.1-96.0	0.0007	2.86	0.25	0.70	b=3	0.75±0.09
Liza ramada	Thinlip grey mullet	Spring	19	12.0 - 22.0	14.1 - 78.7	0.009	2.91	0.31	0.95	b=3	0.72±0.02
		Summer	7	13.0 - 20.0	24.0 - 73.1	0.005	3.20	0.13	0.99	b>3	0.92±0.04
		Winter	8	17.0 - 22.0	37.0 - 80.0	0.004	2.62	0.91	0.80	b=3	0.70±0.20
Mugil cephalus	Flathead grey mullet	Spring	6	5.5 -7.5	1.7 - 4.0	0.053	1.70	0.17	0.91	b<3	0.97±0.20
		Summer	5	7.4 -18.5	3.2 - 55.3	0.009	3.05	0.00	0.94	b=3	1.03±0.30
		Autumn	45	4.5 -8.5	0.95 - 5.39	0.008	3.01	0.01	0.85	b=3	0.81±0.04
Chelon labrosus	Bosega	Spring	29	13.0 - 22.0	22.85 - 68.4	0.019	2.70	0.09	0.87	b<3	0.80±0.10

4. Otolith weight, fish length and otolith length relationships of the red mullet *Mullus barbatus* (Linnaeus 1758)

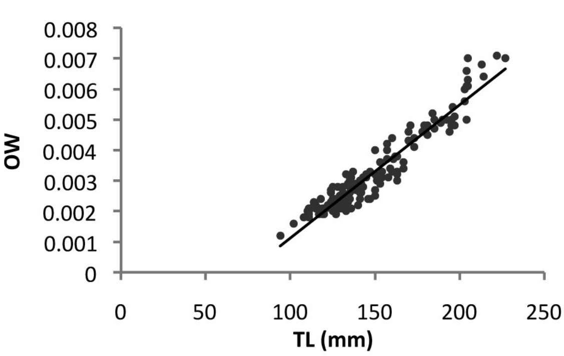
A. Chatzispyrou and A. Anastasopoulou

The red mullet, *Mullus barbatus*, is a benthic species inhabiting sandy and muddy bottoms of the continental shelf along the Mediterranean Sea coasts. Otolith weight (OW) has been explored for many fish species, for population identification, aging and feeding studies as well as for stock assessments (Zan *et al.,* 2015). Otolith size is not used only in ichthyology, but also in a variety of other sciences such as palaeontology, stratigraphy, archaeology and zoogeography (Tuset *et al.,* 2008). The current work investigates, for the first time, the relationship of OW with total length (TL) and otolith radius (R) of *Mullus barbatus*.

For this purpose, a total of 342 specimens were used from the Aegean and Ionian Sea, measuring 94 to 229 mm TL. Otoliths were extracted, cleaned and weighted to the nearest 0.0001 g. Broken or unreadable otoliths were excluded from the analyses. ANOVA analysis was used to test differences between right and left OW. General linear models (GLM) were used to identify the relationships between OW along with the factors area, sex, maturity and the continuous variables TL and R.

There was no statistically significant difference between the left and the right OW (P=0.12), which is in agreement with previous studies indicating that otoliths are a mirror image of each other (Jawad *et al.,* 2011); the left otolith was used for the analyses. The GLM analysis showed that OW was statistically significantly related only with area, TL and R (P<0.05). Thus, otolith growth is correlated with fish growth, as suggested by several authors (e.g. Deghani *et al.,* 2016). The relationships OW-R and OW-TL were examined by area. Linear models best described the relationships in the Aegean Sea (OW = -0.0058 + 0.0058*R, N =158, R^2 = 90.6 and OW = -0.0032 + 0.0001*TL, N =161, R^2 = 91.4, Fig. 2) whereas, power models provided a better explanation of the relationships in the Ionian Sea (OW = 0.001x $R^{2.44}$, N =118, R^2 = 94.8 and OW = 3.19x10^{-7}x $TL^{1.84}$, N= 120, R^2 = 95.3, Fig. 3).

Comparison of the regression lines of the OW-TL relationship between the two studied areas showed that there was a statistically significant difference between the intercepts (P=0.006); this was not the case for the slopes



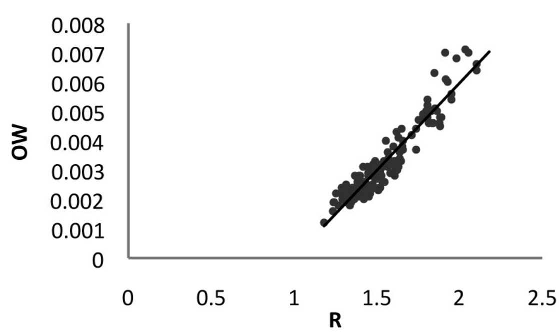


Fig. 2: OW-R and OW-TL relationships in the Aegean Sea.

(*P*=0.49). The opposite occurred for the OW-R relationship, with a statistically significant difference between the slopes only (*P*=0.013). These differences between the Aegean and Ionian Sea might be due to the existence of different population stocks. Fish from different areas may have different allometric otolith growth, which can be attributed to differences in habitat, food availability and physiochemical factors in each region (Deghani *et al.,* 2016).

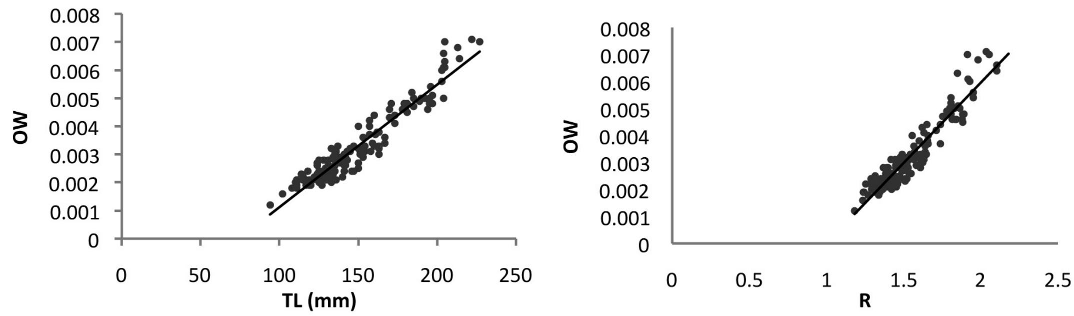


Fig. 3: OW-R and OW-TL relationships in the Ionian Sea.

5. Otolith weight relationships in European hake, *Merluccius merluccius* from the Greek seas

P. Pattoura and Ch. Mytilineou

The relationship between fish length and otolith dimensions, can be useful to estimate the size and age of fish, even in cases where the whole fish is not available as it happens in stomach contents or archaeological samples (Dehghani *et al.,* 2016). In addition, otolith weight (OW) has been found to be a good predictor of age for many species (Pilling *et al.,* 2003). European hake *Merluccius merluccius* is one of the most important and heavily exploited species of Greek demersal fisheries. Therefore, any information derived from biological data is essential and valuable. In this work, we examine the relationships between OW-Total length (TL) and OW-Otolith radius (R) of *Merluccius merluccius* from the Aegean and Ionian Seas.

A total of 282 specimens were collected within the framework of the DCF Program 2013 from the Aegean Sea and the Eastern Ionian Sea, with TL ranging between 82 and 730 mm. Sagittal otoliths were extracted from each specimen and then cleaned and weighed to the nearest 0.0001 g. Differences between left and right otolith were tested using ANOVA analysis. OW was examined to identify relationships with the factors sex, maturity and study area and the continuous variables TL and otolith radius (R) using general linear models (GLM-ANOVA).

ANOVA analysis showed that there was no statistical difference between left and right otolith weight (*P*=0.88). Therefore, only the right otolith was used for the analyses. Based on the GLM-ANOVA, OW was found to be significantly related with sex, TL and R; thus, all analyses were performed by sex for the pooled data of the two geographical areas. The detected significance of sex supports the differences in growth between male and female hake, a fact that has already described in the literature (Mellon-Duval *et al.,* 2010). Power relationships for OW-TL and OW-R were found for both sexes (Fig. 4). The results

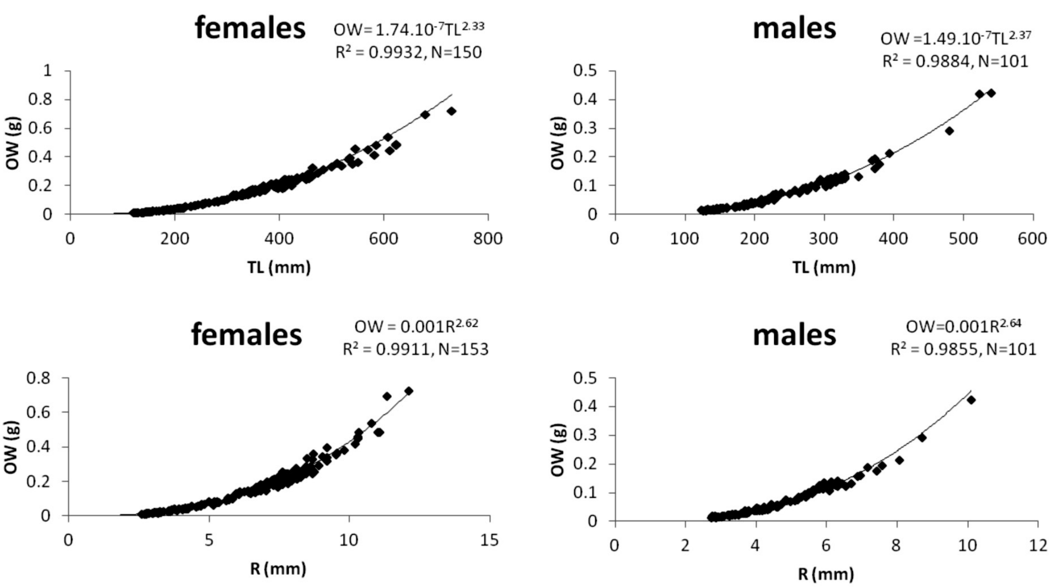


Fig.4: Relationships between OW-TL and OW-R in European hake, *Merluccius merluccius* from the Greek Seas.

indicated that the otolith increases more in weight than in size and that OW increases at a higher rate than fish size. Several authors mention that otolith dimensions and weight are related to fish length mostly by linear models (Jawad *et al.,* 2011). Our results indicate an exponential model, which is in accordance with the results of Zengin *et al.* (2016) for *Pomatomus saltatrix*. Comparison of regression lines showed that for OW-TL relationships, the intercepts differed significantly (P=0.016) between males and females.

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