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Analyzing Growth Studies of Four Mullidae Species Distributed in Mediterranean Sea and Black Sea

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ABSTRACT

This study aims to determine the factors affecting von Bertalanffy growth factors and to demonstrate the relationships between these factors. Accordingly, 65 sets of growth data belonging to 43 studies on the subject of the growth of four Mullidae species prevalent in the Mediterranean (*Mullus barbatus, Mullus surmuletus, Upeneus pori and Upeneus moluccensis*) and the Black Sea (*M. barbatus, M. surmuletus*). It was discovered that the growth parameters, theoretically affected by similar factors, are not affected by every factor at the same time. It was also discovered that the sample structure given in the studies also affects the biological validity of the parameter estimations.

INTRODUCTION

Von Bertalanffy growth factors (VBGF) are parameters needed in stock estimate models, ecosystem models, maximum sustainable product estimations and the estimations of many biological parameters (Apostolidis and Stergiou, 2014; Beddington and Kirkwood, 2005; Cheung *et al.*, 2005; Froese and Binohlan, 2000; Hilborn and Walters, 1992; Pauly *et al.*, 2000). This model, based on a physiological perspective, is widely known and often used in the fisheries sciences (Pauly, 1980; von Bertalanffy, 1957). According to this physiological perspective based by von Bertalanffy on the hypothesis that net growth causes a change in mass as a result of the difference between anabolism and catabolism, a cubic function can demonstrate this metabolic process. This process might differ between species, or even between stocks. For this reason, it is necessary to perform a comparative analysis with different stocks of a given species when establishing the growth characteristics of a species.

Goatfishes are quite significant species for Turkish fisheries. Total fishing amount of these highly valuable goatfishes sum up to 4277 tons (TUIK, 2015) in 2013 based on statistics from Turkish Statistical Institute (TUIK). However, this amount gradually diminishes due to over fishing. For instance, TUIK reports 6557 tons of products for the previous year (TUIK, 2015). This decrease requires reassessment of this species in terms of fisheries management and regulation of the fishing. In addition, growth parameters must be well understood and studied comprehensively for fisheries management.

It is possible to access VBGP data for many species found in the Mediterranean and the Black Sea (Apostolidis and Stergiou, 2014). Most of this data is specifically on economically significant species such as the goatfishes. Goatfishes which are economically very lucrative, now are among the target species of trawl fishing and hence suffer from overfishing (Stergiou, 1990; Golani and Ritle, 1999; Tserpes *et al.*, 2002; Çiçek and Avşar, 2014). There have been many studies on the growth of goatfishes; but none of these were on evaluation of growth of different goatfish stocks. This study aims to cover the gap in this subject, and determine the regional differences and similarities between the growth parameters of four goatfish species. In addition an empirical equation that shows the relationship between maximum size (L_{max}) and L_∞ in directly related observations was intended to be demonstrated in this study. This relationship was investigated at a species and family level.

MATERIALS AND METHODS

In this study, 43 fish specimens of goatfish species prevalent in Mediterranean (*M. barbatus barbatus* (MB), *M. surmuletus* (MS), *U. pori* (UP) *and U. moluccensis* (UM)) and Black Sea (*M. barbatus barbatus* (MB), *M. surmuletus* (MS) were examined. Databases like Web of Science, Scopus, Google Scholar; technical reports and thesis papers were used for this purpose. Twenty one specimens from the total fishes studied were used for estimation of growth parameters separately for females (F) and males (M). Other fish samples were evaluated without distinguishing between genders (B). As a result, 65 growth sets were collected. All samples were classified according to five geographical sub-regions recommended by FAO for the Mediterranean/Black Sea water system as a fishing region (Fig. 1), *viz.*, Western

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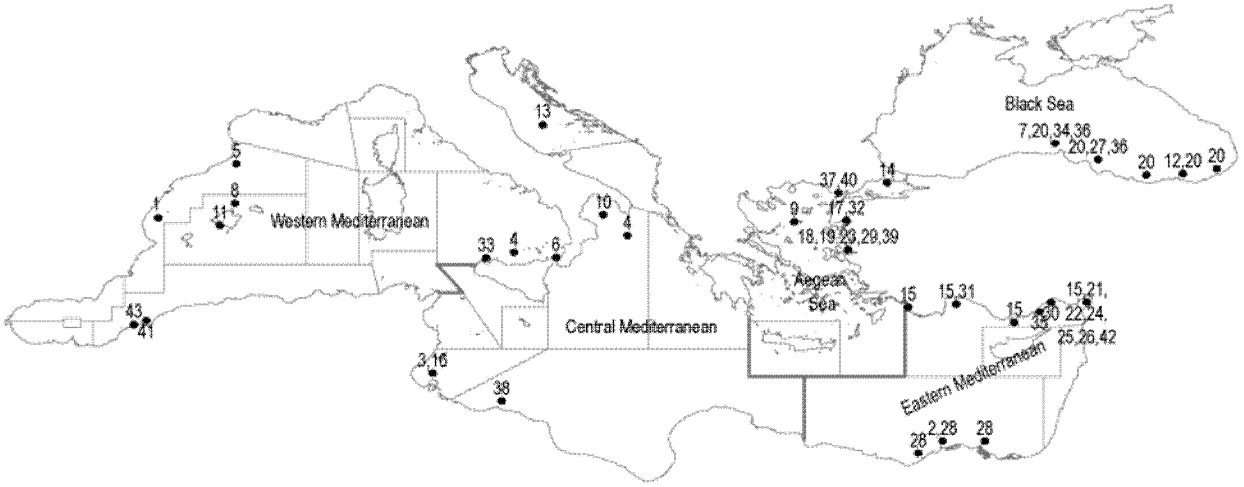

Fig. 1. The locations of the regions where the evaluated studies were performed (codes of studies explained in Table I)

Mediterranean (WM), Central Mediterranean (CM), Aegean Sea (AS), Eastern Mediterranean (EM) and the Black Sea (BS).

The estimation methods in this study were classified as length-frequency analysis (LFD), otolith reading (OR), scale reading (SR) and undetermined (UN). UN however, were disregarded in analysis of impact of these factors. In LFD method t_0 value was calculated using equation (1) as reported by Pauly (1980).

$$\mathrm{Log}_{10}(-t_0)=-03922 - 0.2752\mathrm{Log}_{10}(L_\infty) - 1.038\mathrm{Log}_{10}(K) \quad (1)$$

The data of each variable was analyzed with reference to each specific region. In these cases regional differences were disregarded and species and family differences were focused. The effect of geographical region, sex and age determination method on the growth parameters (L_∞,K, t_0) and L_{max} at the family level was analyzed using separate one way analysis of variance (ANOVA). One way ANOVA was used to determine the parameter differences between species, and to test if regions, sex and age determination methods were different for various parameters for each species. Tukey multiple comparison tests were used to determine the cause of differences discovered by variance analysis (Gündoğdu, 2014). In cases where the number of studies were not sufficient for a multiple comparison, two sample t-tests were used. Pearson multiple correlation test was used to determine the correlation between L_∞, K N (sample size), maximum size (L_{max}) and t_0.

The relationship between L_{max} and L_∞ was investigated proportionally as demonstrated by Froese and Binohlan (2000). An attempt was also made to determine the relationship between L_{max} and L_∞ on both species and family basis (Froese and Binohlan, 2000; Pauly, 1984). L_∞ values reported by the studies were assessed based on the criteria determined by Froese and Binohlan (2000) and Pauly (1984b). The studies where L_∞ value was outside the ± 30% limit of the L_{max} value were classified as problematic. As all studies included all 4 seasons, effects caused by seasonal variations were assumed to be equal for all studies. L_{max} values derived from observations were disregarded when examining the differences caused by age determination methods.

All statistical analysis was performed by IBM SPSS (version 20.0; IBM Corp, Armonk, NY, USA) package software. Significance level was determined as 0.05.

RESULTS

Table I shows data on fish specimens of the family Mullidae from five different regions of Mediterranean/Black Sea waters.

Table II shows descriptive statistics for various parameters of fish samples gathered from literature. The median values of L_∞ for *M. barbatus barbatus*, *M. surmuletus*, *U. moluccensis* and *U. pori* for all regions were 247, 281.15, 247.05 and 205.2 mm, respectively; the median values of K were 0.23 year^{-1}, 0.24 year^{-1}, 0.13 year^{-1} and 0.26 year^{-1}, respectively and the median values of t_0 were found, -1.59 year, -2.15 year, –3.76 year and -1.31 year, respectively. Median values of L_{max} were 207, 237.5, 178 and 162.5 mm, respectively. There were

Table I.- **Sources of information of four species of the family Mullidae in the mediterranean and Black Seas used in this analysis.** (TL, total length; FL, fork length; n.r., not reported; WM, Western Mediterranean; CM, Central Mediterranean; EM, Eastern Mediterranean; AS, Aegean Sea; BS, Black Sea; B, both sex; L.T, length type, OR, otolith reading; LFA, length-frequency analysis; UN, unknown; SR, scale reading)

Code	Species	Area (Sub area)		Author	Sex	N	L.T.	Aging	L_∞ (mm)	K (year^{-1})	t_0 (year)	L_{min} (mm)	L_{max} (mm)	$\frac{L_{max}}{L_\infty}$	L_∞ - L_{max}
1	*M. barbatus*	WM	Spanish	Larrañeta and Roda (1956)	F	1634	TL	LFA	248.8	0.4	-0.2	100	177	0.71	71.8
					M	2147	TL	LFA	181.7	0.59	-0.12	105	226	1.24	-44.3
2	*M. barbatus*	EM	Eygptian Coast	Hashem (1973)	F	223	TL	UN	237	0.28	-0.33	41	240	1.01	-3
					M	180	TL	UN	195.2	0.33	-0.28	41	200	1.02	-4.8
3	*M. surmuletus*	CM	Tunusia	Gharbi and Ktari (1981)	B	202	TL	SR	215.1	0.5	-0.14	80	230	1.07	-14.9
4	*M. surmuletus*	WM	Tyrrhenian Sea	Andaloro (1982)	F	n.r.	TL	UN	301.2	0.24	-2.68	n.r.	n.r.	-	
					M	n.r.	TL	UN	250.2	0.3	-2.39	n.r.	n.r.	-	
5	*M. surmuletus*	WM	Catalan sea	Sanchez *et al.,* (1983)	B	3339	TL	OR	325.2	0.11	-3.65	120	320	0.98	5.2
6	*M. surmuletus*	CM	Strait of sicily	Andaloro and Giarritta (1985)	F	n.r.	TL	UN	297.5	0.49	-0.31	n.r.	n.r.	-	
					M	n.r.	TL	UN	262.5	0.41	-0.23	n.r.	n.r.	-	
7	*M. barbatus*	BS	Central BS	Samsun (1990)	B	2116	TL	OR	295.8	0.1	-3.28	69	253	0.86	42.8
8	*M. surmuletus*	WM	Majorca Island	Morales-Nin (1991)	F	n.r.	TL	OR	297.6	0.24	-3.82	95	270	0.91	27.6
9	*M. surmuletus*	AS	Aegean Sea	Vassilopoulou and Papaconstantinou (1992)	F	336	FL	OR	413.3	0.1	-2.77	90	260	0.63	153.3
					M	451	FL	OR	380.1	0.1	-2.76	100	220	0.58	160.1
10	*M. barbatus*	CM	Ionian Sea	Tursi *et al.* (1994)	B	19116	TL	OR	252	0.26	-1.71	68	236	0.94	16
11	*M. surmuletus*	WM	Majorca Island	Renones *et al.* (1995)	F	1771	TL	OR	319	0.21	-2.61	120	330	1.03	-11
					M	1342	TL	OR	255.4	0.27	-0.21	110	270	1.06	-14.6
12	*M. barbatus*	BS	Eastern BS	Sahin and Akbulut (1997)	F	1190	TL	OR	212.6	0.23	-1.94	80	207	0.97	5.6
					M	1428	TL	OR	210.2	0.2	-2.33	82	195	0.93	15.2
13	*M. barbatus*	CM	Adriatic	Jukic-Peladic and Vrgoc (1998)	B	15933	TL	UN	277.5	0.27	-0.62	55	265	0.95	12.5
14	*M. surmuletus*	BS	Marmara Sea	Moldur (1999)	B	1885	TL	OR	328.2	0.23	-2.13	90	235	0.72	93.2
15	*U. moluccensis*	EM	EM	Kaya *et al.* (1999)	F	535	FL	OR	262	0.11	-4.08	86	178	0.68	84
					M	176	FL	OR	238.6	0.12	-3.69	85	161	0.67	77.6
16	*M. surmuletus*	CM	Tunusia	Jabeur *et al.* (2000)	B	123	TL	OR	223	0.34	-0.79	50	230	1.03	-7
17	*M. barbatus*	AS	Edremit Bay	Celik and Torcu (2000)	B	474	FL	OR	260.8	0.13	-3.54	94.5	197	0.76	63.8
18	*M. barbatus*	AS	Izmır Bay	Akyol *et al.* (2000)	F	110	FL	LFA	225	0.2	-2.3	86	183	0.81	42
					M	218	FL	LFD	270	0.17	-1.84	95	150	0.56	120
19	*M. barbatus*	AS	Izmır Bay	Kınacıgil *et al,* (2001)	B	221	FL	OR	190.3	0.44	-0.78	81	161	0.85	29.3
20	*M. barbatus*	BS	BS	Genç *et al.* (2002)	B	747	TL	OR	242.2	0.22	-1.71	75	207	0.85	35.2
21	*U.pori*	EM	EM	Çiçek *et al.* (2002)	F	461	TL	OR	200.2	0.16	-1.67	65	155	0.77	45.2
					M	534	TL	OR	220.5	0.17	-1.67	63	147	0.66	73.5
22	*U. moluccensis*	EM	Karataş Off	Kökçü (2004)	F	356	TL	OR	279.4	0.09	-4.71	70	180	0.64	99.4
					M	216	TL	OR	251.1	0.11	-4.04	60	160	0.63	91.1
23	*M. barbatus*	AS	Izmir bay	Ozbilgin *et al.* (2004)	B	110891	TL	LFD	242.6	0.57	-0.31	50	230	0.95	12.6
24	*U. moluccesis*	EM	Iskenderun Bay	İşmen (2005)	F	216	TL	OR	243	0.22	-0.92	70	205	0.84	38
					M	202	TL	OR	225	0.24	-0.92	70	178	0.79	47
25	*M. barbatus*	EM	Karataş Off	Çiçek (2006)	B	212	TL	OR	219.8	0.19	-1.17	69	157	0.71	62.8
25	*U. pori*	EM	Karataş Off	Çiçek (2006)	B	247	TL	OR	219.8	0.19	-1.17	63	155	0.71	64.8

Continued

Code	Species	Area (Sub area)		Author	Sex	N	L.T.	Aging	L_∞ (mm)	K ($year^{-1}$)	t_0 (year)	L_{min} (mm)	L_{max} (mm)	$\frac{L_{max}}{L_\infty}$	L_∞ - L_{max}
26	*U. pori*	EM	Iskenderun Bay	Işmen (2006)	F	324	TL	OR	185	0.42	-0.63	70	170	0.92	15
					M	292	TL	OR	179	0.37	-0.89	66	151	0.84	28
27	*M. barbatus*	BS	Central BS	Süer (2008)	F	449	TL	OR	393.6	0.08	-1.92	75	225	0.57	168.6
					M	736	TL	OR	252.5	0.15	-1.59	85	205	0.81	47.5
28	*M. surmuletus*	EM	Eygptian Coast	Mehanna (2009)	B	1385	TL	OR	317.4	0.47	-0.3	100	320	1.01	-2.6
29	*M. surmuletus*	AS	Gulf of İzmir	İlhan *et al.* (2009)	B	192	TL	OR	278.5	0.19	-1.58	66	226	0.81	52.5
30	*M. barbatus*	EM	Mersin Bay	Atar and Mete (2009)	B	297	TL	OR	279	0.11	-3.47	105	185	0.66	94
31	*U. moluccensis*	EM	Antalya Bay	Ozvarol *et al.* (2010)	B	464	TL	OR	255.6	0.14	-3.83	80	211	0.83	44.6
32	*M. surmuletus*	AS	Edremit Bay	Üstün (2010)	B	520	TL	OR	250.9	0.14	-2.48	77	170	0.68	80.9
33	*M. barbatus*	WM	Castellammare	Sieli *et al.* (2011)	F	578	TL	OR	221.2	0.38	-0.94	90	245	1.11	-23.8
34	*M. barbatus*	BS	Central BS	Aksu *et al.* (2011)	B	699	TL	LFD	201.5	0.33	-0.28	73	187	0.93	14.5
35	*M. barbatus*	EM	NE Levant	Ok (2012)	B	18894	TL	LFD	260	0.56	-0.51	30	250	0.96	10
35	*U. pori*	EM	NE Levant	Ok (2012)	B	3577	TL	LFD	200	0.45	-0.67	50	190	0.95	10
					B	1208	TL	LFD	170	0.60	-0.52	70	160	0.94	10
36	*M. barbatus*	BS	BS	Aydin and Karadurmus (2013)	F	950	TL	LFD	254	0.14	-2.70	95	215	0.85	39
					M	485	TL	LFD	193	0.35	-0.75	64	170	0.88	23
37	*M. surmuletus*	AS	Saros Bay	Arslan and İşmen (2013)	F	184	TL	OR	283.8	0.19	-2.16	110	268	0.94	15.8
					M	119	TL	OR	269.4	0.2	-2.34	118	198	0.73	71.4
38	*U. pori*	CM	Cost of Libya	El-Drawany (2013)	F	252	TL	OR	211.5	0.25	-1.71	70	175	0.83	36.5
					M	234	TL	OR	210.2	0.27	-1.44	70	175	0.83	35.2
39	*M. barbatus*	AS	İzmir Bay	Irmak (2013)	F	125	FL	OR	193.3	0.23	-2.6	50	153	0.79	40.3
40	*M. barbatus*	AS	Saros Bay	Arslan and İşmen (2014)	F	2302	TL	OR	265.8	0.18	-1.75	92	236	0.89	29.8
					M	1308	TL	OR	283	0.14	-2.39	88	241	0.85	42
41	*M. surmuletus*	WM	Algerian Coast	Kherraz *et al.* (2014)	F	516	TL	LFD	247	0.37	-0.37	120	240	0.97	7
					M	322	TL	LFD	255.2	0.32	-0.71	125	235	0.92	20.2
42	*M. barbatus*	EM	Iskenderun Bay	Gündoğdu and Baylan (2014)	B	422	FL	OR	247	0.27	-0.33	62	275	1.11	-28
43	*M. barbatus*	WM	Algerian Coast	Chafika (2015)	B	1697	TL	LFD	288.8	0.59	-0.08	83	277	0.96	11.8

Table II.- **Descriptive statistics of collected data (S.E.: Standard error of mean).**

		Mullus barbatus barbatus			*Mullus surmuletus*			*Upeneus moluccenses*			*Upeneus pori*		
		Mean±SEM	**Range**	**Median**	**Mean±SEM**	**Range**	**Median**	**Mean±SEM**	**Range**	**Median**	**Mean±SEM**	**Range**	**Median**
L_∞ (mm)	WM	235.13±22.58^{a}	181.7-288.8	235	281.3±11.58^{a}	247-325.2	276.5						
	CM	264.75±12.75^{a}	252-277.5	264.75	249.5±19.06^{a}	215.1-297.5	242.75				210.85±0.65^{a}	210.2-211.5	210.85
	AS	241.35±12.48^{a}	190.3-283	251.7	312.6±27.3^{a}	250.9-413.3	281.15						
	EM	239.67±12.1^{a}	195.2-279	242	317.4±0	317.4-317.4	317.4	240.59±11.6	170-279.4	247.05	200.75±7.01^{a}	179-220.5	200.1
	BS	250.6±20.88^{a}	193-393.6	242.2	328.2±0	328.2-328.2	328.2						
	Total	244.6±8.05^{2*}	181.7-393.6	247	288.5±11.08^{3}	215.1-413.3	281.15	240.6±11.6^{2}	170-279.4	247.05	203.3±5.39^{1}	179-220.5	205.2
K (year^{-1})	WM	0.49±0.06^{a}	0.38-0.59	0.5	0.26±0.03^{b}	0.11-0.37	0.26						
	CM	0.27±0.01^{b}	0.26-0.27	0.27	0.44±0.04^{c}	0.34-0.5	0.45				0.26±0.01^{a}	0.25-0.27	0.26
	AS	0.26±0.06^{b}	0.13-0.57	0.19	0.15±0.02^{a}	0.1-0.2	0.17						
	EM	0.29±0.06^{b}	0.11-0.56	0.28	0.47±0	0.47-0.47	0.47	0.2±0.06	0.09-0.6	0.13	0.29 ±0.05^{a}	0.16-0.45	0.28
	BS	0.2±0.03^{b}	0.08-0.35	0.2	0.23±0	0.23-0.23	0.23						
	Total	0.28±0.03^{1}	0.08-0.59	0.23	0.27±0.03^{1}	0.1-0.5	0.24	0.2±0.06^{1}	0.09-0.6	0.13	0.29±0.04^{1}	0.16-0.45	0.26
t_0 (year)	WM	-0.34±0.2^{a}	-0.94 - -0.08	-0.16	-2.06±0.51^{b}	-3.82 - -0.21	-2.5						
	CM	-1.17±0.55^{c}	-1.71 - -0.62	-1.17	-0.37±0.15^{a}	-0.79 - -0.14	-0.27				-1.58 ±0.14^{a}	-1.71 - -1.44	-1.58
	AS	-1.94±0.36^{b}	-3.54 - -0.31	-2.07	-2.35±0.18^{b}	-2.77 - -1.58	-2.41						
	EM	-1.02±0.51^{c}	-3.47 - -0.28	-0.42	-0.3±0	-0.3 - -0.3	-0.3	-2.84±0.61	-4.71 - -0.52	-3.76	-1.12±0.19^{a}	-1.67 - -0.63	-1.03
	BS	-1.83±0.31^{b}	-3.28 - -0.28	-1.92	-2.13±0	-2.13 - -2.13	-2.13						
	Total	-1.44^{1}	-3.54 - -0.08	-1.59	-1.72±0.27^{1}	-3.82 - -0.14	-2.15	-2.84±0.61^{2}	-4.71 - -0.52	-3.76	-1.23±0.16^{1}	-1.71 - -0.63	-1.31
L_{max} (mm)	WM	231.2±20.92^{c}	177-277	235.5	277.5±16.21^{a}	235-330	270						
	CM	250.5±14.5^{a}	236-265	250.5	230^{a}	230-230	230				175±0^{a}	175-175	175
	AS	193.8±13.43^{b}	150-241	190	223.6±15.1^{a}	170-268	223						
	EM	217.8±18.16^{c}	157-275	220	320±0	320-320	320	179.13±7.01	160-211	178	161.33±6.56^{a}	147-190	155
	BS	207.1±7.84^{c}	170-253	207	235±0	235-235	235						
	Total	212±6.8^{2}	150-277	207	251.4±11.05^{1}	170-330	237.5	179.1±7.01^{3}	160-211	178	164.7±5.29^{3}	147-190	162.5
N	WM	1514±332	578-2147	1666	1458±540	322-3339	1342						
	CM	17525±1592	15933-19116	17525	163±40	123-202	163				243±9	234-252	243
	AS	14456±13779	110-110891	348	300±66	119-520	264						
	EM	3371±3105	180-18894	260	1385±0	1385-1385	1385	422±122	176-1208	286	906±536	247-3577	393
	BS	978±177	449-2116	747	1885±0	1885-1885	1885						
	Total	6406±3862	110-110891	736	846±238	119-3339	451	422±122	176-1208	286	740±407	234-3577	308

*Numbers above total mean values indicate differences and similarities between different species for each parameter and signs above the regional mean values indicate the differences and similarities within each species with regards to regions) significant differences for all the three parameters of all fish species ($p<0.05$). But no significant difference was found with regards to the K parameter. When a species based von Bertalanffy equation was prepared using these values, following equations were derived (Fig. 2).

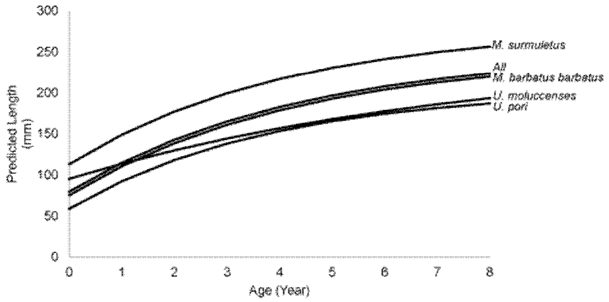

Fig. 2. Predicted length at age fit of four Mullidae species and all.

M. barbatus barbatus: $L_t= 247.9\ (1 - e^{-0.23(t-1.59)})$ (2)
M. surmuletus: $L_t = 281.15\ (1 - e^{-0.24(t-2.15)})$ (3)
U. moluccenses: $L_t = 247.05\ (1 - e^{-0.13(t-3.76)})$ (4)
U. pori: $L_t = 250.2\ (1 - e^{-0.26(t-1.31)})$ (5)

When L_∞, K, L_{max} and t_0 for the Mullidae family were calculated without differentiating between species and regions, median levels were found to be 250.9 mm, 0.23 year^{-1}, 207 mm and -1.67 year, respectively. Based on this, the von Bertalanffy growth equation of the Mullidae family was empirically determined as;

$$L_t= 250.1\ (1 - e^{-0.23(t-1.67)}) \quad (6)$$

The growth curves drawn using the equations (2), (3), (4), (5) and (6) are shown in Figure 2. As can be seen, the growth curve of the entire family is similar to *M. barbatus barbatus*. Since only *M. barbatus barbatus* and *M. surmuletus* were studied in all regions, only these two species were tested with regards to the regions using one way ANOVA.

M. barbatus barbatus

When all parameters (L_∞, K L_{max} and t_0) were compared based on regions, a difference was discovered for all parameters except L_∞ ($p<0.05$; Table II). When we excluded studies that did not contain any information about age determination method, the remaining two methods (LFD and OR) were compared and it was found that K and t_0 displayed a variation between regions ($p<0.05$), but L_∞ had no differences ($p>0.05$). When examined based on sex, none of the parameters had any significant variance ($p>0.05$). Regression equation between L_∞ and L_{max} and the r^2 value was determined as;

$$\ln(L_\infty) = 3.238 + 0.421 \ln (L_{max}) \ (n=25, r2 = 0.197, s.e. = 0.156) \ (7)$$

The variance analysis result of equation (7) was determined to be significant ($p<0.05$). According to this, for *M. barbatus* equation (7) can be used for estimation of L_∞ given L_{ma}.

M. surmuletus

Since *M. surmuletus* had more than two values in three regions (WM, CM, AS) these were compared in these three regions. According to this, K and t_0 parameters showed significant difference based on regions ($p<0.05$), however no differences were found for L_{max} ve L_∞ ($p>0.05$; Table II). When age determination methods were compared, no difference was discovered for any parameters other than the K parameter ($p>0.05$). For the K parameter, it was discovered that the studies using LFD and OR methods had the same K value, and those using the SR method had a different K value. No difference was found for any of the four parameters in comparisons based on sex ($p>0.05$). Regression equation between L_∞ and L_{max} and the r^2 value was determined as;

$$\ln(L_\infty) = 3.587 + 0.376 \ln (L_{max}) \ (n=19, r^2 = 01.36, s.e. = 0.173) \ (8)$$

The variance analysis of data obtained through equation (8) was not found significantly different ($p>0.05$). This means equation (8) can not be used for the estimation of L_∞ when L_{max} is given for *M. surmuletus.*

U. moluccensis

Since all studies on *U. moluccensis* were focused on the EM region, no regional comparisons were made (Table I). Since only LFD and OR methods were used for age determination, the differences between these methods were examined and it was discovered that t_0 showed no difference ($p>0.05$) and that L_∞ and K were different ($p<0.05$). Again it was checked whether there was any difference in estimates and L_{max} between sexes and no difference was discovered ($p>0.05$). Regression equation between and L_{max} and the r^2 value was determined as;

$$\ln(L_\infty) = 2.511 + 0.572 \ln (L_{max}) \ (n=8, r^2 =01.67, s.e. = 0.148) \ (9)$$

The variance analysis of data from equation (9) showed its significance ($p>0.05$). This means equation (9) cannot be used for the estimation of L_∞ when L_{max} is given for *U. moluccensis*.

U. pori

Since *U. pori* were focused only on EM and CM (Tables I, II) regions, these two regions were compared with regards to all parameters. None of the four parameters showed any regional differences ($p>0.05$; Table II). Likewise OR and LFD did not show any difference in all the three parameters ($p>0.05$). Regression equation between L_∞ and L_{max} and the r^2 value was determined as;

$$\ln (L_\infty)=5.579-0.052 \ln(L_{max}) \; (n=8, r^2 =0.04, s.e. = 0.082) \quad (10)$$

The variance analysis result of equation (10) was determined to be significant ($p>0.05$). This means equation (10) can not be used for the estimation of L_{max} when L_∞ is given for *U. pori*.

Mullidae

On an examination on a family level without differentiating between species and genus, it was determined that no parameters other than L_{max} showed any difference (Table III). When age determination methods were examined, it was discovered that there was no difference in L_∞ but there was a difference in K and t_0 (Table III).

Regression equation between L_∞ and L_{max} and the r^2 value with regards to the family was determined as;

$$\ln(L_\infty) = 2.607 + 0.544 \ln (L_{max}) \; (n=63, r^2 =0345, s.e. = 0.154) \quad (11)$$

The variance analysis result of equation (11) was determined to be significant ($p<0.05$). According to this, for Mullidae, equation (11) can be used to estimate of L_∞ given L_{max}.

When correlations between parameters and between the number of observations and L_{max} were examined, a significant negative correlation between L_∞ and K (-0.402) was determined. Along with this, a statistically significant positive correlation between L_∞ and L_{max} (0.576) was observed. Existences of positive and negative correlations between other parameter combinations were also found (Table IV, Fig. 3). When ratio L_{max}/L_∞ was examined, it was noted that all samples were between 0.5 and 1.5 as stated in Froese and Binohlan (2000) (Table I). Again when the difference between L_∞ - L_{max} was investigated, it was noted that 10 of the 61 growth sets had a negative (*i.e.* $L_\infty < L_{max}$), and 51 had a positive (*i.e.* $L_\infty > L_{max}$) difference (as L_{max} wasn't reported for 4 growth sets, these studies weren't included; Table I). 44 of the L_∞ values that were estimated were within the ±30% limit given in Pauly (1984) and Froese and Binohlan (2000). L_∞ estimates of the remaining 17 samples were outside this limit.

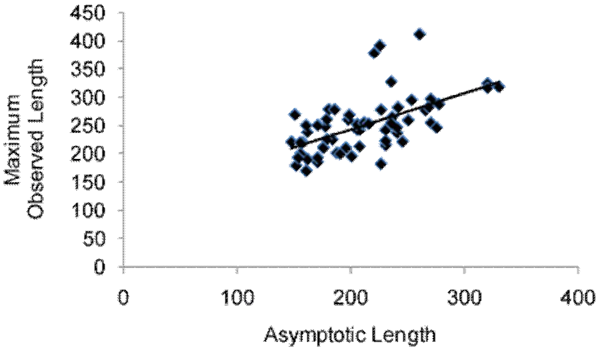

Fig. 3. Relationship between asymptotic length and maximum observed length.

DISCUSSION

The data used in this study coming only from four species of total of 85 species of Mullidae family should be considered insignificant, since it has been demonstrated that (Froese and Binohlan, 2000; Von Bertalanffy, 1957) species with similar size were distributed almost at similar places on the same regression line and moreover belonged to different species. The empirical equations and results reached by this study can be comfortably used for all Mullidae member species, which is the main claim of this study. The results of this study will, however, be discussed with reference to Mullidae family, if not for all fishes.

These four members of the Mullidae family are heavily studied species in the Mediterranean and the Black Sea. Most of these studies focus on growth. Usually either a single stock of a single species was examined or multiple stocks of a single species were studies comparatively (Table I). No studies that cover the Mediterranean in its entirety other than the study where Bianchini and Ragonese, (2011) gathered previous studies on *M.barbatus barbatus* were noted.

The inter-species differences between growth parameters are regulated by physiological, environmental, geographical, nutritional and similar factors (Jobling, 1997). Also, the methods used to estimate the growth parameters and the sampling methods can also cause differences within the species (Biro and Post, 2008; Pardo *et al.*, 2013; Pilling *et al.*, 2002; Taylor *et al.*, 2005). This is primarily demonstrated by the limitation of size frequency distribution of sampled individuals by the use of size-selective fishing

Table III.- **Descriptive statistics of family level parameters with regards to age determination method and regions. (S.E.: Standard error of mean; Superscripted numbers indicate statistically significant differences both between parameters and aging methods, and study area)**

		L_∞		K		t_0		L_{max}	
		Mean	**Median**	**Mean**	**Median**	**Mean**	**Median**	**Mean**	**Median**
Aging	LFD	231.3 ± 9.6^{a}	244.8	0.41 ± 0.04^{a}	0.38	-0.81 ± 0.2^{a}	-0.51	206.4±10.1	202.5
	OR	259.1 ± 8.2^{a}	252	0.21 ± 0.01^{b}	0.19	-2.1 ± 0.2^{b}	-1.92	211.5±7.4	205
	Total	252.3 ± 6.7^{a}	250.9	0.25±0.02	0.22	-1.78±0.2	-1.71	210.3±6.1	205
Area	WM	263.9 ± 14.1^{a}	255.3	0.35 ± 0.05^{a}	0.34	-1.27 ± 0.5^{a}	-0.54	259 ± 14.2^{a}	257.5
	CM	224.2 ± 9.7^{a}	217.2	0.28 ± 0.02^{a}	0.26	-1.41 ± 0.3^{a}	-1.57	204 ± 16.8^{b}	202.5
	AS	271.9 ± 16.3^{a}	267.6	0.21 ± 0.03^{a}	0.18	-2.11 ± 0.2^{a}	-2.32	$206.6\pm10.5^{a,b}$	209
	EM	234.3 ± 8.7^{a}	238.6	0.26 ± 0.04^{a}	0.19	-1.85 ± 0.3^{a}	-1.17	188.8 ± 10.6^{b}	178
	BS	258.4 ± 20.2^{a}	247.3	0.21 ± 0.03^{a}	0.21	-1.86 ± 0.3^{a}	-1.93	$209.9\pm7.5^{a,b}$	207
	Total	252.3 ± 6.7^{a}	250.9	0.25±0.02	0.22	-1.78 ± 0.2^{a}	-1.71	210.3±6.1	205

Table IV.- **Correlations between parameters.**

		N	L_∞	**K**	t_0	L_{max}
N	Pearson Correlation	1				
	Sig. (2-tailed)					
	N	60				
L_∞	Pearson Correlation	0.003	1			
	Sig. (2-tailed)	0.980				
	N	60	65			
K	Pearson Correlation	0.328^{*}	-0.402^{**}	1		
	Sig. (2-tailed)	0.01	0.001			
	N	60	65	65		
t_0	Pearson Correlation	0.176	-0.383^{**}	0.771^{**}	1	
	Sig. (2-tailed)	0.177	0.002	0.000		
	N	60	63	65	65	
L_{max}	Pearson Correlation	0.129	0.576^{**}	0.112	0.076	1
	Sig. (2-tailed)	0.327	0.000	0.39	0.56	
	N	60	61	61	61	61

$^{**}p<0.01$

tools (Biro and Post, 2008; Taylor *et al.*, 2005). This causes the differentiation of captured L_{max} value. Again, size frequency distribution in a limited range affects the estimates that would be reached using the LFD analysis as a method (Pauly and David, 1981). It also causes differences to appear in age determination using otolith. Limited size frequency distribution means a limited age group was captured, and that affects the estimates of L_∞, K and t_0. Froese, (2006) argues that a good and effective growth study would be achieved if a sampling method that has an equal chance of capturing all size groups. To understand this, examining Table I might be advisable. For example, Çiçek (2006) worked in a very narrow size range like 69-157 mm and as a result reached an unrealistic t_0 (-1.17) and as a result estimated a L_∞ value that is outside the limit of ± 30% of L_{max} (219.8 mm). Sparre and Venema, (1998) state that t_0 value must be close to zero and, L_∞ value must be close to the L_{max} value. However, this can be affected by different factors that can't be explained solely by a narrow sample structure. Again Froese and Binohlan (2000) stated that L_∞ - L_{max} of difference should be close to zero. The chief among these is the fishing pressure, and all four Mullidae members are under severe pressure of overfishing (Stergiou, 1990).

It was argued by some authors that *M. barbatus* might demonstrate nanism specific to the Levantine region of the Mediterranean and the L_{max} value estimated here might be smaller than the other regions (Azov, 1991; Bianchini and Ragonese, 2011; Maurin, 1970; Sonin *et al.*, 2007). However, this study did not reveal any finding like that at least with regards to the reported studies.

However, the existence of a significant difference between EM and WM with regards to L_{max} should be discounted. While this does not provide sufficient evidence for nanism, different environmental factors might have an effect on this difference. (Jobling, 1997; Helser *et al.,* 2007).

The estimated size-age graph shown in Figure 2 demonstrates that all four species have a similar growth trend. But the estimated size values for each age group demonstrated that *M. surmuletus* is one group, the entire family and *M. barbatus* are one group, and *U. moluccensis* and *U. pori* are one group. This is thought to be a result of the nutrition, anabolism, catabolism, breeding period etc. of the species involved. Also, the reason *M. barbatus* showing almost the same growth curve as the entire family is thought to be the highest number of studies among all on the family being on *M. barbatus.*

Situations where growth parameters vary by both regional and age determination methods are supported by literature as well. Apostolidis and Stergiou (2014) have stated that otolith misreading during age determination also affects growth parameters. Thus different age determination methods result in different growth parameter estimates. Helser *et al.* (2007) has posited that the geographical differences between growth parameters might be related to the bio-ecological characteristics of the ecosystem the stock is in. This situation is explained similarly by (Froese, 2006) as well.

The correlations between parameters have a negative inclination according to Beverton (1992), Helser *et al.* (2007), Pilling *et al.* (2002) and von Bertalanffy (1957). However, Pilling *et al.* (2002) state that these negative correlations are statistical, not biological. This means real populations are far from offering clear evidence on this subject. When Table III is examined, it can be seen that the correlations between parameters are low but statistically significant. For example, the -0.402 correlation between K and L_∞ doesn't fit the strong negative correlation state posited in the theory. It must be noted that these correlation values were calculated together for all species. Otherwise, when considered for each species separately, the correlation values drop even lower.

The ratio between L_{max} and L_∞ appears to be on the 0.5 - 1.5 range for all studies. This means it is within the limits established by Froese and Binohlan, (2000). However, the regression relationship between L_{max} and L_∞ while statistically important, was not considered strong. For example, when all species are considered, only 34.5% of the change in L_∞ can be explained by L_{max}. This means there are more factors that must be explained. Considering the state established by Sparre and Venema, (1998) with regards to the difference between L_∞ - L_{max} when the differences between L_∞ - L_{max} are examined, it can be noted that the L_∞ estimates derived from 10 growth sets are contrary to biological reality. Because these 10 growth sets imply that the stock worked on contains fishes that are larger than the size the fishes could have reached in infinity. The ±30% limit implied by Pauly (1984) and Froese and Binohlan (2000) was breached by 17 growth sets, marking these studies as problematic studies.

As a result, VBGP are affected by many factors. The examination of all these factors together is very difficult due to the limits of the data provided in the studies reported in literature. However, both multi-species and multi-stock analyses examining main involved factors like geographical region and age determination method would be very beneficial for the fishing management of the involved species. This study demonstrates that age determination, sample composition and regional differences somehow affects VBGP estimations. Pardo *et al.* (2013) states von Bertalanffy parameters are quite important for biomass estimation and that non-realistic estimates could affect biomass estimation and hence, stock estimations. Therefore, it is clear that conducting more of such studies is necessary considering the importance of stock estimation on preparing fishing method plan.

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