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RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

A regional evaluation of lessepsian migrant *Upeneus moluccensis* (Bleeker, 1855) length and weight relationships from the Mediterranean Sea

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Abstract : The length and weight relationships (LWRs) of goldband goatfish found in the coasts of Cyprus was studied, and both prediction capacity of the model as well as a regional prediction capacity by testing developed models from the Mediterranean basin were evaluated. A total of 219 individuals were obtained monthly between November 2017-April 2018. LWR models taken from total length and fork length measurements were developed for female and male samples and combined with a maximum 36% error in estimations. Results indicated that LWR modelling based on sexes does not provide any improvement for uncertainty in the estimations. Evaluations of previously developed models indicate that the majority share a similar performance regarding the distribution of error in estimations. In conclusion, the population of this species shows that there are similar growth properties in both sexes throughout the eastern Mediterranean. Using the same TLWR model for all individuals is therefore applicable for the purpose of further modelling within the Mediterranean basin-scale.

Keywords: *Upeneus moluccensis, goldband goatfish, LWR, uncertainty, Eastern Mediterranean*

INTRODUCTION

The goldband goatfish *Upeneus moluccensis* (Bleeker, 1855) is a lessepsian migrant Mullidae and is often found among the commercial catch of many fisheries within the Mediterranean Sea (İşmen, 2005; Das, 2011; Pazhayamadom *et al.*, 2017). Preferring to live in mostly sand, muddy sand or gravel bottoms, at depths ranging from 10 to 120 m, this species distributes itself along the western Indian Ocean stretching from the Red Sea to southern Oman (Ben-Tuvia & Golani, 1989; Golani, 1994). The habitual presence of the Mullidae species *Mullus surmuletus, M. barbatus, Parupeneus forsskali, Upeneus moluccensis* and *U. pori* in Cyprus is already known from previous studies (e.g., Çoker & Akyol, 2014; Iglésias and Frotté, 2015), however studies on their biological traits is limited. This lack of information is particularly apparent regarding goldband goatfish in Cyprus (EastMed, 2010; Iglésias and Frotté, 2015) and studies in Northern Cyprus have yet to be conducted. The biology of this species and its portion within local fisheries has, however been studied at length along the Mediterranean coast and, more specifically, along the eastern coasts of the island (Golani, 1990; Golani and Galil, 1991; Golani 1994; Torcu, 1994; Kaya et al., 1999; İşmen, 2005; Kökçü, 2004; El-drawany 2012; Edelist 2014; Mehanna 2018).

In fisheries management, prohibition is the preferred means by which commercial fisheries protect immature individuals inhabiting a coastal area (Özyurt et al., 2014). Hence, knowledge about the basic biology of a species is essential for its sustainable management. Collating length and weight data and estimations on their relationships (LWRs) is therefore standard practice for any such management plan (Kohler et al. 1996, Schneider et al. 2000). Adding to the importance of collecting length measurements is the benefit that this type of data is particularly useful when computing the biomass of fish samples (Kuriakose, 2017); especially for stock assessment (Gulland, 1983). Such estimations are also practical for studies on stock modelling in long time series and wide spatial coverage. However, as this approach can cause uncertainty in estimations, careful considerations and regional assessments provide an important contribution to understanding the estimation limits of these modelling efforts.

In the LWR equation ($W=aL^b$), *a* is the coefficient of body shape, with values around 0.1 for small sized fishes with a rounded body shape, 0.01 for streamlinedshaped fishes and 0.001 for eel-like shaped fishes. In contrast, *b* is the coefficient balancing the dimensions of the equation and its value can be lower, higher or equal to 3.00. In the first two cases, results of *b* indicate (i.e., $b<3.00$ and $b>3.00$) that fish growth is allometric (i.e., when $b<3.00$ the fish grows faster in length than in weight, and when $b>3$ the fish grows faster in weight than in length), whereas when $b=3.00$ growth is isometric (Karachle and Stergiou 2012). These results provide information on the species population dynamics in addition to a baseline for further studies and management plans.

The aim of this study is to determine the LWR of goldband goatfish for the first time in the coasts of north Cyprus. A further aim of this study is to understand the prediction capacity of the produced models as well as prediction capacities of other developed models evident within the eastern Mediterranean. By evaluating the prediction capacities of developed models, it is possible to contribute to fisheries management strategies on both a regional scale and in north Cyprus.

MATERIAL AND METHOD

Individuals were obtained between November 2017-April 2018monthly from fishermen in Yenierenköy and Gazi Mağusa (Figure 1) and the length and weight of each individual was measured. Length measurements were made using a measuring board with a sensitivity of 1 mm, and weight measurements were taken from an electronic scale with a sensitivity of 0.01 g. Sex stage determinations were made through macroscopic observation of the gonad. The gonadal development of both sexes was analyzed using the five-stage sexual maturity scale by Holden and Raitt (1974).

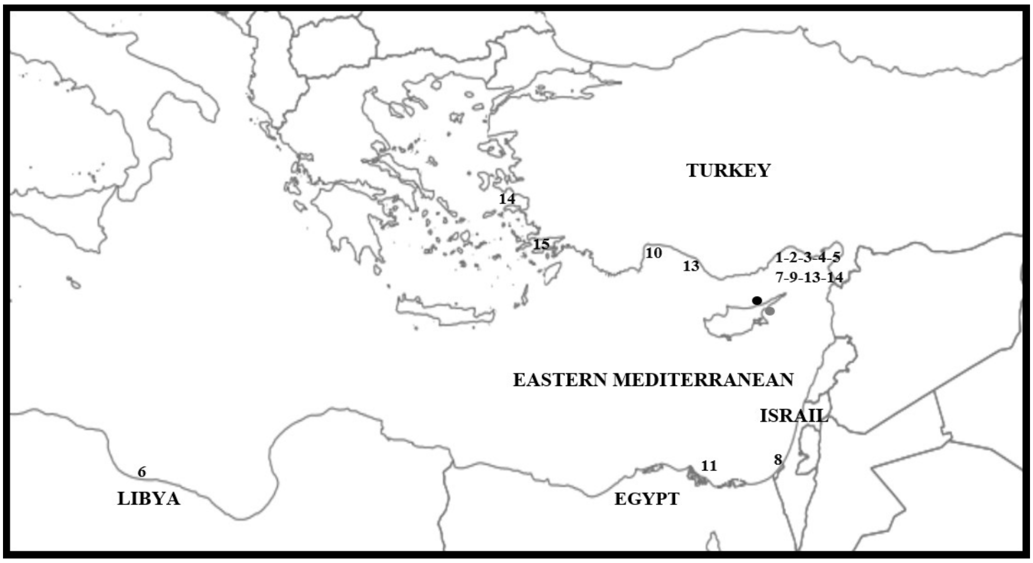

Figure 1. Map of the study area and sampling areas of previous studies (Black and grey dot represents sampling areas of this study; TLWR 1-Taşkavak and Bilecenoglu, 2001; 2-Ismen, 2005; 3-Çiçek et al., 2006; 4-Sangun et al., 2007; 5-Kökçü, 2004; 6-El-drawany, 2012; 7-Ergüden et al., 2009; 8-Edelist, 2014; 9-Gökçe et al., 2010; 10-Özvarol, 2014; 11-Mehanna, 2018; FLWR 13-Torcu, 1994; 14-Kaya et al., 1999; 15-Ceyhan et al., 2009).

The length-weight relationships (LWR) were calculated by using power relationship in the following equation:

$$W=aL^b \quad (1)$$

Where W is the total weight (g); L is the total length (TL) or fork length (FL) (cm), while *a* and *b* are constants for each species or population (Schneider et al. 2000). The constants were estimated by using the logarithm transformation in LWRs dataset of the study. The length and weight relationships were estimated for each sex and combined, along with the total length and fork length for easy comparison. The *b* value, which indicates growth tendency, was tested to verify whether it differs from the isometry at a 0.05 significance level.

In order to quantify the estimation performance of each LWR model, TLWR and FLWR, the percentage of error were calculated by using the following formulas:

$$T_{pe} = \frac{w_t - w}{w} \times 100 \quad (2)$$

$$F_{pe} = \frac{w_f - w}{w} \times 100 \quad (3)$$

Where T_{pe} is the percentage error from total length; w_t is the estimation of weight by using the model developed from total length; w is the weight from measurements; F_{pe} is the percentage error from fork length; and W_f is the estimation of weight by using the model developed from fork length.

These formulas were used to evaluate the performance of estimated data sets from total length and fork lengths measured in this study for all data and both sexes. Additionally, LWR models from previous studies and presented in Table 1 were also evaluated for comparison.

Table 1. LWRs reported by other authors and produced ones from this study (FL: Fork Length; TL: Total Length; N: number of individuals; A: all; F: females; M: males)

Reference	Study period	Sex	N	LWR	R^2	Area
Torcu (1994)	1990-93	A	1040	$W=0.005349FL^{3.21}$	0.95	Fethiye & Mersin Bay
Kaya et al. (1999)	1991-92	F	535	$W=0.06071FL^{3.35}$	0.92	Kusadası & Iskenderun Bay
		M	176	$W=0.01051FL^{3.15}$	0.94	
Taşkavak & Bilecenoğlu (2001)	1997-98	A	265	$W=0.0000135TL^{3.02}$	0.97	Mersin & Iskenderun Bay
İşmen (2005)	1999-00	A	418	$W = 0.0113TL^{3.01}$	0.99	Iskenderun Bay
		F	216	$W = 0.0097TL^{3.00}$	0.99	
		M	202	$W = 0.0118TL^{2.99}$	0.99	
Çiçek et al. (2006)	1999-00	A	975	$W = 0.0055TL^{3.30}$	0.99	Mersin Bay
Sangun et al. (2007)	2001-03	A	651	$W=0.0024TL^{3.56}$	0.98	Levantine Sea
Kökçü (2004)	2002-03	F	356	$W=0.0092TL^{3.08}$	0.91	Karatas, Iskenderun Bay
		M	216	$W=0.0009TL^{3.09}$	0.89	
Ceyhan et al. (2009)	2006	A	51	$W = 0.0046FL^{3.11}$	0.93	Gokova Bay
El-drawany (2012)	2006-07	M	426	$W = 0.01017TL^{3.01}$	0.99	Libya
		F		$W = 0.00822TL^{3.09}$	0.99	
Ergüden et al. (2009)	2007-08	A	297	$W = 0.0034TL^{3.44}$	0.95	Iskenderun Bay
Edelist 2014	2008-11	A	162	$W = 0.0085TL^{3.10}$	0.95	Coasts of Israel
Gökçe et al. (2010)	2010	A	5	$W = 0.00590TL^{3.24}$	0.99	Iskenderun Bay
Özvarol (2014)	2012-13	A	93	$W = 0.0053TL^{3.23}$	0.81	Antalya Bay
Mehanna (2018)	2015-16	A	-	$W = 0.0119TL^{3.04}$	0.98	Port Said Region, Egypt
This study	2017-18	A	219	$W = 0.0045TL^{3.32}$	0.96	Coasts of North Cyprus
		F	149	$W = 0.0045TL^{3.32}$	0.96	
		M	64	$W = 0.0085TL^{3.29}$	0.92	
		A	219	$W = 0.0068FL^{3.33}$	0.95	
		F	149	$W = 0.0074FL^{3.30}$	0.95	
		M	64	$W = 0.0065FL^{3.36}$	0.93	

RESULTS

A total of 219 individuals (149 females, 64 males) were obtained during the period of this study. Individuals ranged from 10.40 – 18.80 cm (mean is 14.70) in TL, 9.20 -16.70 cm (mean is 12.86) in FL and 10.00 – 82.45 g (mean is 36.35) in W. The data distribution showed that females were larger than males in size (Figure 2a). While the mean-average values of parameters (TL, FL and W, respectively) were: 15.21 cm, 13.30 cm and 40.46 g for females, the males were found to be: 13.65 cm, 11.94 cm and 27.76 g, respectively.

LWR relationships (TLWR and FLWR) with high regression coefficients (>0.90) were observed in data sets for each sex and combined. However, with regards to regression coefficient, the LWRs from combined and female data sets showed a better performance than those of the males. LWR models developed from this study are presented in Table 2.

The model' growth tendency of the population in the coasts of north Cyprus shows a significantly positive allometry (p<0.05). This positive allometry was obvious (min. 3.41) and did not show any significant difference among the sexes or the combined group (p<0.05).

Results of LWR models within this study from the total length showed a similar range of percentage error between 53.24% (combined and female) and 52.26% (male). The mean percentage error was from -0.05% (combined) to 1.20% (male). Results from fork length models indicated that the range of percentage error was slightly narrower in males (46.06%) than in other groups (approximately, 63%). However, the mean percentage error showed a better performance in the combined group (0.12 %) rather than the other groups (0.28% and 1.01% in female and male, respectively). Descriptive statistics on error analysis of all LWR models used were presented in Table 3. A distribution of the percentage error for all LWR models in this study indicated that the percentage error dispersed mostly around zero with no bias, while a big portion of data-sets had a percentage error distribution between -10% and 10% (Figure 2b).

Table 2. LWR and LLR (length and length relationship) produced from this study (A: all, F: female, M: male, TL: Total length, FL: Fork Length, W: Weight)

Sex	N	Relationship Type	Relationship	R^2	CI 95%	CI 95%
A	219	TL-W	$W = 0.0045TL^{3.32}$	0.96	3.41	3.23
		FL-W	$W = 0.0068FL^{3.33}$	0.95	3.43	3.23
F	149	TL-W	$W = 0.0045TL^{3.32}$	0.96	3.43	3.21
		FL-W	$W = 0.0074FL^{3.30}$	0.95	3.43	3.18
M	64	TL-W	$W = 0.0085TL^{3.29}$	0.92	3.53	3.04
		FL-W	$W = 0.0065FL^{3.36}$	0.93	3.60	3.12

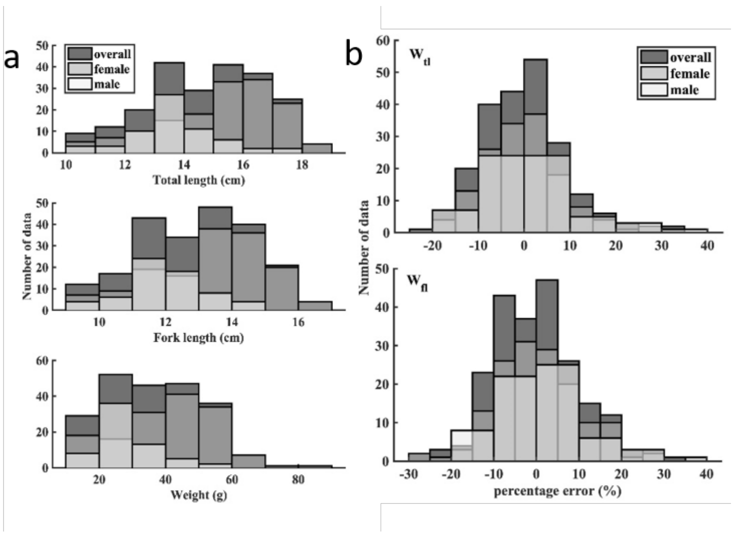

Figure 2. (a) Distribution of data set measured in this study; (b) Distribution of percentage error estimated from TL (W_{tl}) and FL (W_{fl})

Table 3. Descriptive statistics of percentage error distribution for all LWR models, which are developed or tested in this study

Model	Type	Median	Mode	Mean	Min	Max	Range
	A	-0.23	4.08	-0.05	-21.26	31.98	53.24
Wtl (This study)	F	-0.4	-18.91	-0.2	-21.26	31.98	53.24
	M	1.07	6.32	1.2	-18.23	34.03	52.26
Taşkavak and Bilecenoğlu (2001)	A	99.87	99.85	99.87	99.81	99.89	0.08
	A	-6.52	-25.27	-9.07	-50.90	11.81	62.71
İşmen (2005)	F	11.96	-4.68	9.99	-26.30	26.35	52.65
	M	-8.26	-24.78	-10.45	-49.81	10.28	60.09
Çiçek et al. (2006)	A	-1.73	-9.24	-2.78	-37.06	17.40	54.46
Sangun et al. (2007)	A	-1.14	1.60	-2.12	-29.87	25.38	55.25
Kökçü (2004)	F	-4.03	-20.19	-6.02	-46.62	12.98	59.59
	M	-9.30	-21.95	-10.75	-48.97	9.99	58.96
El-drawany (2012)	F	4.59	-9.99	2.68	-34.35	20.08	54.43
	M	1.75	-12.75	-0.29	-35.81	18.53	54.34
Ergüden et al. (2009)	A	-3.29	-3.78	-3.46	-34.17	21.40	55.57
Edelist (2014)	A	-2.14	-16.54	-4.36	-42.48	15.06	57.53
Gökçe et al (2010)	A	-4.04	-12.58	-5.35	-40.85	14.89	55.74
Özvarol (2014)	A	8.79	1.00	7.61	-23.68	25.16	48.84
Mehanna (2018)	A	-21.38	-41.61	-24.45	-71.42	-0.85	70.57
	A	-0.13	4.68	0.12	-28.53	34.34	62.87
Wfl (This study)	F	-0.47	16.36	0.28	-28.30	35.69	63.99
	M	1.40	-5.71	1.01	-18.78	27.29	46.06
Torcu (1994)	A	13.30	4.98	11.93	-18.29	28.19	46.47
Kaya et al. (1999)	F	6.99	-7.22	6.55	-25.31	33.06	58.38
	M	3.02	-7.40	1.82	-26.14	19.81	45.95
Ceyhan et al. (2009)	A	62.38	54.13	61.76	46.99	73.16	26.17

A total of 19 LWR models composed from total and fork length from the Mediterranean basin were used to test their performance and compared correspondingly with six LWR models developed in this study. The model by Taşkavak and Bilecenoğlu (2001) from TL were found to be most biased with a 99.87% mean percentage error and a very narrow and positive biased range between 99.81%-99.89%. Another positive biased model, where fork length was used, was found to be Ceyhan et al. (2009) with a range of percentage error from 46.99% to 73.16% (mean is 61.76). The model of Mehanna (2018) was the only negative biased model with a -24.45% mean percentage error and a wide negative range from -0.85% to -71.48%. Mean percentage errors were mostly between -10% and 10% for the other models (Table 3). The TLWR model of Sangun et al. (2007) showed a relatively better performance among combined models, while the TLWR models of El-drawany (2012) had a better performance among models based on sexes. The distribution of percentage error of each TLWR and FLWR model for combined and each sex based data-set were presented in Figure 3.

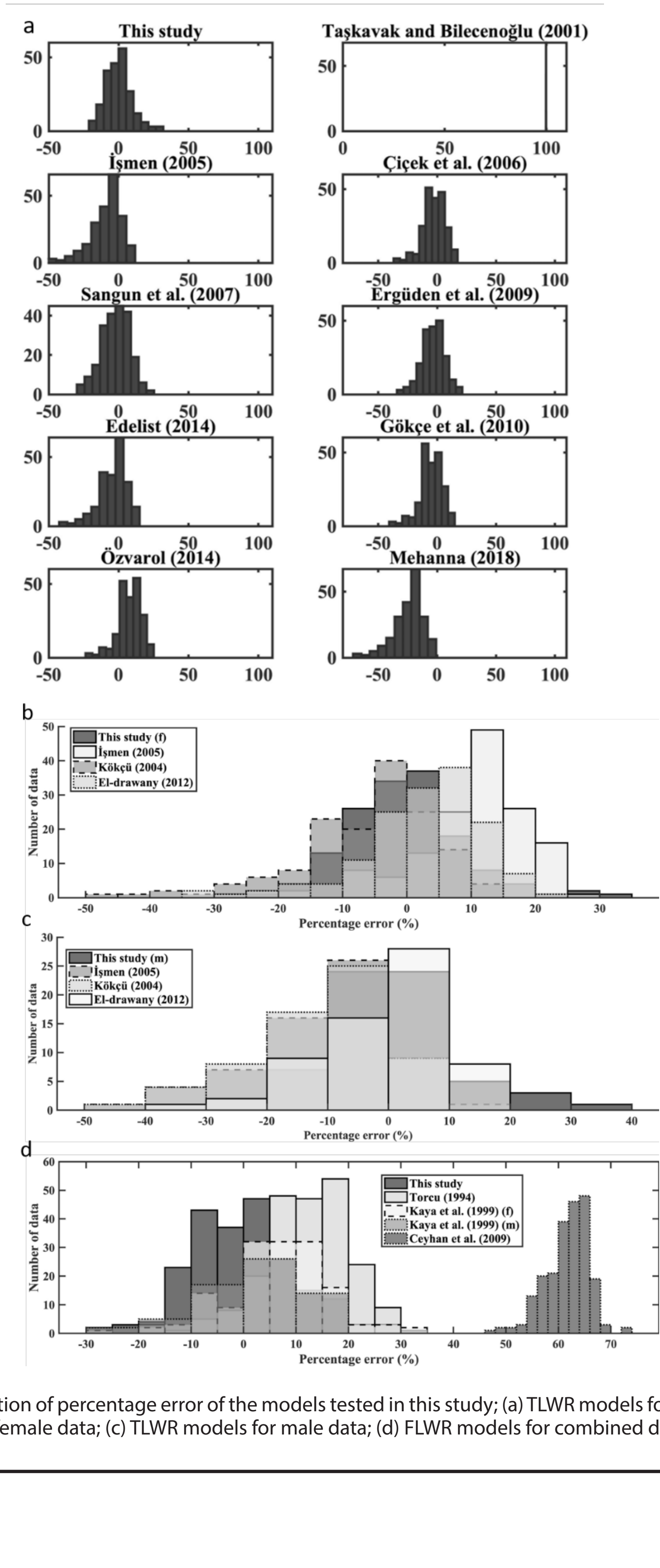

Figure 3. Distribution of percentage error of the models tested in this study; (a) TLWR models for combined data; (b) TLWR models for female data; (c) TLWR models for male data; (d) FLWR models for combined data

DISCUSSION

The species studied for this research is a lessepsian species and has already become one of the most common fish being caught in the Mediterranean. It is therefore important to understand the specific biological information of this species in the region. Results indicated that goldband goatfish showed a positive allometric growth in the coasts of north Cyprus further supporting previous studies from the Mediterrnean, details of which are given in Table 1 [except Ismen (2005) which reported isometric growth for this species]. It should also be noted that *b* values range between 2.99 and 3.56. It may be possible to explain that this range is a result of differences in sample sizes (Table 1) or the methodological approaches used for the study. Significantly different *b* values in the same geographical region and during the same time period encourages the consideration of methodological differences, rather than two different sexes, two distinctive populations or growth periods in the same area.

The *b* value represents the body form, is directly related to weight, and is affected by ecological factors (temperature, food supply, and spawning conditions) in addition to other factors (sex, age, fishing time, area, and fishing vessels) (Ricker, 1973; Froese, 2006). The geographical distribution of the obtained *b* values indicated a decreasing pattern from the north-eastern Mediterranean (e.g.) towards the central and southern Mediterranean (e.g. Libya, Kuşadası Bay, Gökova Bay, Israel, Egypt) with the exception of a report of isometry [Ismen (2005) from Iskenderun Bay] (see Figure 1 for study codes). However, estimations of the model did not show any gradual pattern or bias in accordance with geographical changes. Therefore, the indication of the *b* value may have been caused by an uncertainty in the measurements.

The LWR models developed in this study from both fork and total length of combined, female and male samples, did not show any significant differences ($p<0.05$). Instead they displayed similar performances thus assisting a distribution of the percentage error. This similarity was also reported by Padhayamadom et al. (2017) whereby it was claimed that there is no sexual dimorphism of the species. Thus, it is recommended that a model for all individuals is used rather than stratified models based on sexes due to computational simplification. Similar performances have also been observed in the distribution of percentage error in most of the models developed throughout the Mediterranean. These findings therefore encourage the option of using a TLWR model for the whole basin. On the other hand, however, the studies with fork length are still limited and insufficient for evaluation throughout the basin. Following the TLWR model (Eq. 3), which was developed synthetically by making use of the available previous models developed in the basin, it is suggested for any other studies covering the basin in its entirety that:

$$W=0.0047TL^{3.32} \qquad (4)$$

An evaluation of the model performance showed that most of the models have similar outputs in estimation and error distribution. Cumulative probabilities of the percentage error obviously show that the models have a constant error range, demonstrated by an increasing sampling fraction for the species (Figure 4). Besides having a few bias models, similar error distributions for the model points out that the uncertainty of morphometrical measurements was the reason for determining the error characteristics.

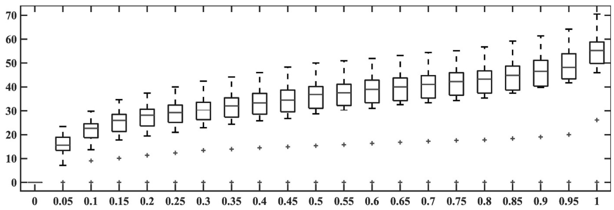

Figure 4. Cumulative distribution of error percentages of previous LWRs of combined individuals applied to this studies data

In conclusion, LWR models for *U. molucensis* were developed for the first time for the coasts of north Cyprus, and it can be stated that this species is one of the most commercially valuable lessepsian species in the Mediterranean Basin. Results indicated that the population around Cyprus has similar growth properties with the populations in the basin. An evaluation of the obtained results also showed that the same TLWR model for all individuals will be satisfactory for both a modelling and basin-scale purpose. Information produced from this study thus contributes to future management plans of the species stock.

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