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ARAŞTIRMA MAKALESİ **RESEARCH PAPER**

Some Morphometric Relationships of Wels Catfish (*Silurus glanis* L., 1758) Inhabiting Sıddıklı Dam Lake (Kırşehir, Turkey)

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Abstract: This study aims to investigate the relationships among morphometric characters of Wels catfish with total length and find the best model to assess relationships. A total of 198 fish samples was caught in Sıddıklı Dam Lake between September 2015 and August 2016 in this study. The morphometric measures taken were: Total length (TL), Anal fin length (AFL), pectoral fin rays length (PFRL), body height (BH), head length (HL), and head height (HH). No significant differences were noted between the pectoral fin rays (PFRL) of females and males, while the significant differences were observed in the other morphometric measurements (TL, AFL, BH, HL, and HH) of females and males. The linear and non-linear model were used to determine relationships between morphometric characters and total length. The linear model is the best fit for all relationships, so this model is preferred for all calculates. All relationships were highly significant ($P < 0.001$, $r^2 > 0.81$) and the mean percent prediction errors were less than 10%. We found that AFL, PFRL, BH, HL, and HH are a good indicator for fish total length and are important for determining the length of Wels catfish. However, the best model was the relationship between anal fin length and total length for estimation of fish length in males and females. The data of the study provides novel information on relationships between morphometric characters for Wels catfish.

Keywords: Linear relationships, morphometric characters, Sıddıklı dam lake, wels catfish.

Sıddıklı Baraj Gölü (Kırşehir, Türkiye)'nde Yaşayan Yayın Balığı (*Silurus glanis* L., 1758)'nın Bazı Morfometrik İlişkileri

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Öz: Bu çalışmada yayın balığının morfometrik karakterleri ile total boyu arasındaki ilişkileri araştırmak ve ilişkileri değerlendirmek için en iyi modeli bulmak amaçlanmıştır. Bu çalışmada, Eylül 2015 ile Ağustos 2016 yılları arasında Sıddıklı Baraj Gölü'nde toplam 198 balık örneği yakalanmıştır. Alınan morfometrik ölçüler şunlardır: total boy (TL), anal yüzgeç uzunluğu (AFL), pectoral yüzgeç uzunluğu (PFRL), vücut yüksekliği (BH), kafa uzunluğu (HL) ve kafa yüksekliği (HH). 'Dişi ve erkeklerin pektoral yüzgeç ışınları (PFRL) arasında anlamlı bir fark gözlenmezken, diğer morfometrik ölçümlerde (TL, AFL, BH, HL ve HH) anlamlı farklılıklar tespit edilmiştir. Morfometrik karakterler ile total boy arasındaki ilişkileri belirlemek için doğrusal ve doğrusal olmayan modeller kullanılmıştır. Doğrusal modelin tüm ilişkiler için en uygun olduğu belirlenmiştir. Bu nedenle bu model tüm hesaplamalar için tercih edilmiştir. Tüm ilişkiler yüksek derecede anlamlı olup ($P <0.001$, $r2> 0.81$) ortalama yüzde tahmin hatalarının % 10'dan daha az olduğu saptanmıştır. AFL, PFRL, BH, HL ve HH'nin balık total boyunun iyi bir göstergesi olduğu ve yayın balığı boyunu belirlemek için önemli olduğu tespit edilmiştir. Ancak, erkek ve dişilerde balık boyunun tahmini için en iyi model anal yüzgeç uzunluğu ile total boy arasındaki ilişkidir. Çalışmanın verileri, yayın balığı için morfometrik karakterler arasındaki ilişkiler hakkında yeni bilgiler sunmaktadır.

Anahtar kelimeler: Linear ilişkiler, morfometrik karakterler, Sıddıklı baraj gölü, yayın balığı.

INTRODUCTION

One of the major keys in fish biology study is morphometric characters since these characters use to understanding taxonomy and anatomy (Ünlü et al., 2012), growth variability (Jawad & Al-Janabi, 2016), sexual differences (Gogoi & Goswami, 2015), and stock status (Alhassan et al., 2015) of fish. In general, morphological features were indicated diversity both within and between fish populations. Morphometric characters considered as measurable structures and are characters describing different external body parts of fish. These characters commonly used in fish biology studies to measure discreteness between different fish stocks (Qadri et al., 2017), and to detect phylogeny of the fish population (Turan, 2004).

The morphometric relationships between different body characters of fish can be used to assess the well-being of individuals and to determine possible differences between separate unit stocks of the same species (King, 2007). The relationships between morphometric characters can be a tool to estimate back-calculate fish length from morphometric characters (Bostancı et al., 2014). Morphometry studies covered these relationships provide important information in the fish biology field including species diet, feeding behavior, ecological strategies, niche partitioning, habitat use and trophic structure.

The objectives of this study are to: i: reveal equations of relationships between morphometric characters and fish length, ii: test the accuracy of the back-calculated lengths using predictive equations. Moreover, this manuscript ensures the first information on the morphometrics relationships of *Silurus glanis*.

MATERIAL AND METHODS

Sıddıklı Dam Lake located near 40 km west of Kırşehir province was built for irrigation purposes. The volume of Sıddıklı Dam Lake is 28.5 hm^3, surface area is 1.65 km^2, body height is 53 m and was completed in 1998. It was put into operation in 2009 (Yazıcı, 2018).

A total of 198 fish samples collected between September 2015 and August 2016 in Sıddıklı Dam Lake were examined for analyzing relationships between some measurable morphometric characters and fish length. Samples were caught by using gills nets with a mesh size ranging from 17 to 35 mm 50 m long and 40 to 80 mm 100m long. The six measurements of the morphometric characters were given in Table 1. The total length (TL) of each fish specimens were measured with approximately 0.1 cm precision. The morphometric characters were taken by using a digital caliper. The sex of samples was detected by the examination of gonads macroscopically.

Table 1. Definitions of morphometric measurements of Wels catfish in Sıddıklı Dam Lake.

Morphometric character	Abbreviation	Description on Fish
Total length	TL	from tip of snout to the end of the caudal fin
Anal fin length	AFL	distance measured in a straight line between the anterior most and posterior most junctions with the body.
Pectoral fin rays length	PFRL	the length of the longest find ray of pectoral fin.
Body height	BH	maximum depth of body
Head length	HL	the length from the nostril tip of nose to the back end of the opercular bone.
Head height	HH	distance along the broadest part of the head in ventral position.

Linear ($y = a+bx$) and non-linear ($y = a*x^b$) regression equations were used to determine what equations best described the relationships between morphometric characters and fish length. The model with the highest coefficient of determination (r^2) was chosen to describe these relationships. Where 'y' is the dependent variable, 'x' is the independent variable, 'a' is a constant (intercept) and 'b' the regression coefficient (slope). The mean percent prediction errors for each regression were determined averaging the percent prediction error calculated for each observation. The percent prediction error (% PE) for an individual is computed by the following formula (Scharf et al., 1998):

$$\%PE = \frac{|Observed - Predicted|}{Predicted} \times 100$$

The t-test was used to compare the outcomes of morphometric measurements between sexes. Paired t-test was used for determining the difference in measurements of left and right pectoral fin rays length. Differences between coefficients of regressions generated separately for females and males were tested by analysis of covariance (ANCOVA) (Zar, 1999). All data were analyzed using the Minitab 17 software program. All the statistical analyses were considered at the significance level of 5% ($P<0.05$).

RESULTS

A total of 198 (female= 98, male= 100) samples were analyzed for morphometric relationships. However, a total of 171 (female= 78, male= 93) Wels catfish samples were used for the relationship between pectoral fin rays length (PFRL) and total length (TL) owing to damaged and lost pectoral fin rays.

The descriptive statistics of fish length (TL) and measurable morphometric characters (AFL, BH, HL, and HH) are given in Table 2. The significant differences were observed in the morphometric measurements (TL, AFL, BH, HL, and HH) of females and males (t-test, $p<0.05$, Table 2). Hence, regressions were generated separately according to both sexes (Figure 1). No significant differences were determined between the slopes "b" of TL-AFL, TL-BH, TL-HL, and TL-HH relationships in females and males (ANCOVA, $p> 0.05$).

Table 2. The descriptive statistics of fish total length (TL, cm), anal fin length (AFL, cm), body height (BH, cm), head length (HL, cm) and head height (HH, cm) of Wels catfish sampled from Sıddıklı Dam Lake.

Variable	Sex	n	Mean± Sd	Min-Max	t-test
TL	Female	98	55.76±13.11	21.80-107.50	p<0.05
	Male	100	60.33±16.79	20.10-151.60	
AFL	Female	98	30.54±6.96	11.90-56.10	p<0.05
	Male	100	33.55±9.10	11.00-83.80	
BH	Female	98	8.36±2.56	2.60-22.40	p<0.05
	Male	100	9.17±3.33	2.10-29.40	
HL	Female	98	10.28±2.71	4.00-20.50	p<0.05
	Male	100	11.23±3.43	3.80-31.80	
HH	Female	98	4.25±1.26	1.10-8.70	p<0.05
	Male	100	4.66±1.52	1.10-14.20	

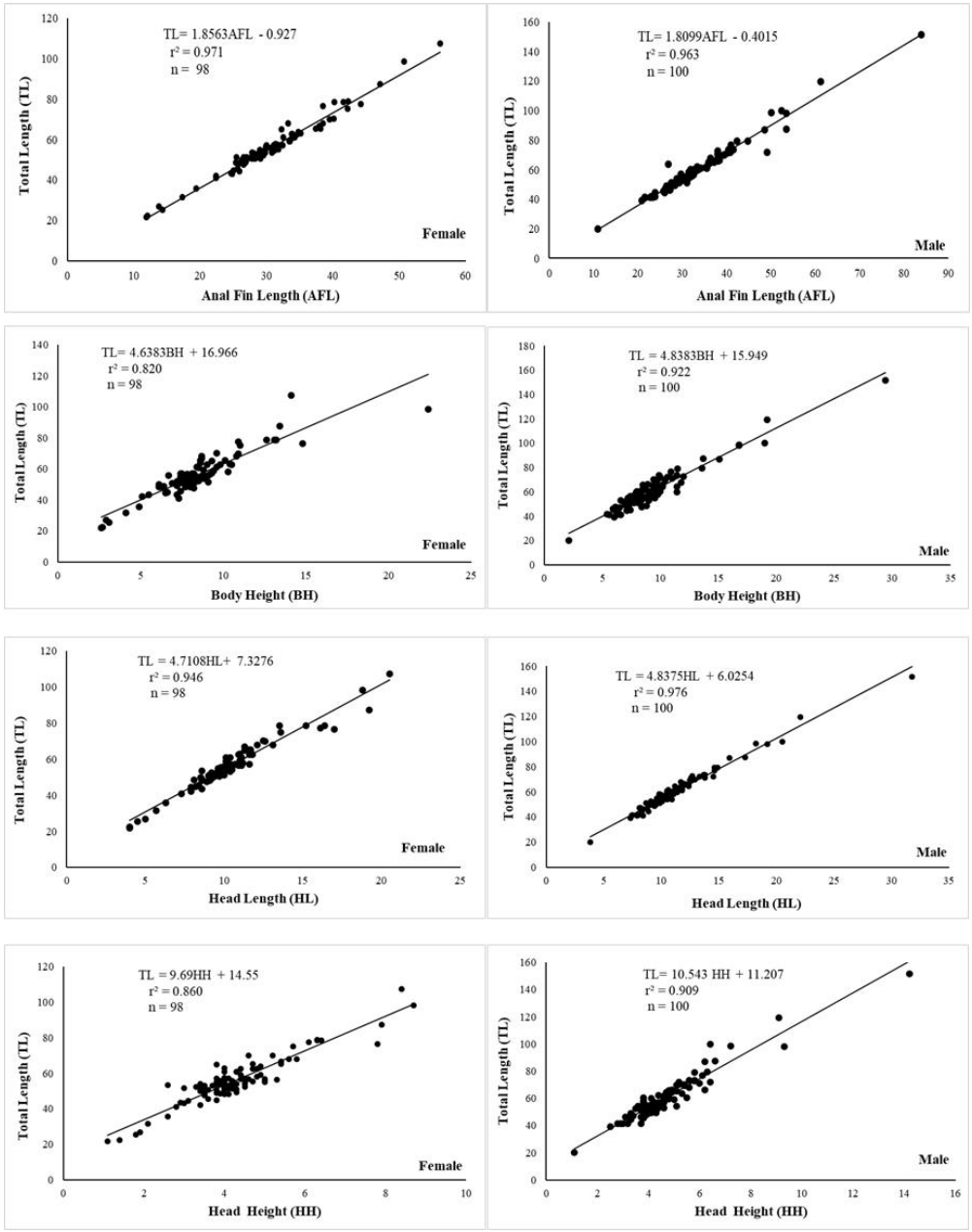

Figure 1. The relationships between morphometric characters and total length in females and males of Wels catfish.

The descriptive statistics of fish length (TL) and pectoral fin rays length (PFRL) are summarized in Table 3. There was no significant difference between the right and left pectoral fin ray length (paired t-test, $p>0.05$) (Table 3).

Table 3. The descriptive statistics of fish total length (TL, cm) and pectoral fin rays length (PFRL, cm) of Wels catfish sampled from Sıddıklı Dam Lake.

Variable	Sex	n	Mean± Sd	Min-Max	t-test
TL	Female	78	57.11±13.74	21.80-107.50	p>0.05
	Male	93	59.80±14.21	20.10-119.50	
	Total	171	58.57±14.02	20.10-119.50	
PFRL	Female	78	4.08±1.19	1.10-8.40	p>0.05
	Male	93	4.25±1.18	1.00-9.10	
	Total	171	4.17±1.18	1.00-9.10	

Therefore, the right pectoral fin rays lengths were chosen for the generation of regression equations. No significant difference was also observed in the pectoral fin rays length between females and males (t-test, p>0.05). Therefore, the variables were pooled for further analysis (Figure 2).

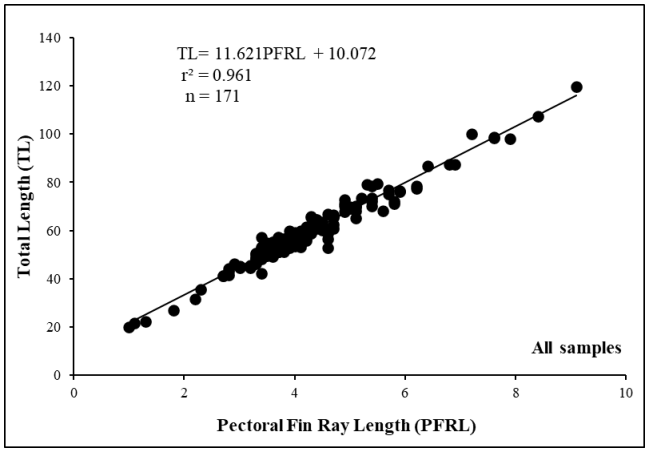

Figure 2. The relationship between pectoral fin ray length and total length in all samples.

The coefficient (r^2) of linear relationships was higher than non-linear relationships. The linear regression model provided the best fit for all relationships. For this reason, linear relationships were established for morphometric analysis. The mean values of all morphometric characters in male individuals were higher than females (Table 2 and 3). The coefficients (r^2) of all linear regressions in males were calculated as higher than females, except anal fin length (AFL) (Figure 1). All regression analyses were highly significant (P<0.001) and analysis of morphometric characters versus TL indicated that the regression models explained more than 82% of the variance (Figure 1). Morphometric characters of Wels catfish were positively relevant to fish length, with r^2 values ranging between 0.820 and 0.977. According to sex, the best fit relationships were found between AFL-TL, and HL-TL among all morphometric characters. The fish total length (TL) was determined as approximately 1.81 times (TL/AFL) of anal fin length for the entire sample.

The mean percent prediction errors ranged from 2.941 to 7.216. The anal fin length (AFL) had the lowest value of mean %PE in females, while head width (HH) had the highest value of mean %PE in females (Table 4). The regression with high r^2 yielded had the lowest mean % PE values (Table 4). For all morphometric characters, there was no significant difference between observed and predicted TL values in both females (t-test; p>0.05) and males (t-test; p>0.05).

Table 4. The mean percent prediction error (%PE) values for morphometric characters in *S. glanis* from Sıddıklı Dam Lake.

Variable	Sex	n	Observed TL (cm)		Predicted TL (cm)		%PE	
			Range	Mean±SD	Range	Mean±SD	Range	Mean±SD
AFL	Female	98	21.80-107.50	55.76±13.11	21.16-103.21	55.76±12.92	0.011-12.187	2.941±2.374
	Male	100	20.10-151.60	60.33±16.79	19.51-151.27	60.33±16.48	0.018-32.214	2.960±3.952
BH	Female	98	21.80-107.50	55.76±13.11	29.03-120.86	55.76±11.88	0.000-30.515	7.048±5.971
	Male	100	20.10-151.60	60.33±16.79	26.11-158.20	60.33±16.12	0.152-23.016	6.290±4.771
HL	Female	98	21.80-107.50	55.76±13.11	26.17-103.90	55.76±12.76	0.012-16.701	3.886±3.657
	Male	100	20.10-151.60	60.33±16.79	24.41-159.86	60.33±16.59	0.009-17.650	3.433±3.657
HH	Female	98	21.80-107.50	55.76±13.11	25.21-98.85	55.76±12.16	0.087-34.360	7.216±6.041
	Male	100	20.10-151.60	60.33±16.79	22.80-160.92	60.33±16.01	0.113-27.094	5.894±4.745
PFRL	Total	171	20.10-119.50	58.57±14.02	21.69-115.82	58.57±13.74	0.009-16.730	3.606±3.151

DISCUSSION

There were several researches on the age (Yılmaz et al. 2007; Saylar, 2009; Alp et al., 2011; Saylar, 2014), growth (Carol et al., 2009; Copp et al., 2009; Uysal et al., 2009; Alp et al., 2011), reproduction (Yazıcı et al., 2018), morphological characters (Ünlü et al., 2012), and the diet (Czarnecki et al., 2003; Bora & Gul, 2004; Alp, 2017) of Wels catfish. However, no studies were conducted on the morphometric biometry of this species. Therefore, this study presents the first data on this subject in Wels catfish.

Generally, linear functions are preferred and mostly used to determine the relationship between body dimensions and length of the fish (Begum et al., 2008; Šantić et al., 2011; Jawad & Al-Janabi, 2016). In this study, both linear and non-linear models were analyzed for defining the relationships between morphometric variables and fish length. Linear model was provided higher regression coefficient than non-linear model for all relationships. Consequently, linear model was preferred for our analysis. Similarly, these relationships in many previous studies were also defined using this model for various fish species (Hajjej et al., 2011; Keč & Zorica, 2011; Balai et al., 2017).

One of the major keys in fish biology is morphometric characters since morphometric analysis

included these characters plays a key role to estimate relationships among various body parts. Morphometric characters in female and male may not be provide the same result in back-calculation of fish length (Begum et al., 2008). In current study, results of testing the difference between the measurements of morphometric characters in females and males showed significant difference. Thus, the regressions were generated separately according to both sexes. These results agree with results of other studies (Begum et al., 2008; Amin et al., 2014; Yilmaz et al., 2014). On the other hand, there were no sexual differences in relationships between pectoral fin length and total length. So, the measurements of males and females were pooled to calculate this relationship.

Differences in the measurement data of same body parts mostly depend on the fish samples quality. Damages as morphological can be seen in fish (e.g. lost or damaged body part such as anal fin, tail, and body length). This status may make measurements difficult. Measurements from intact body parts can be used to calculate length of other body parts. The results of study suggested that the all morphometric relationships are well suited to the prediction of fish length. Among relationships, the anal fin length and head length measurements are important for determining the total length of Wels catfish.

In conclusions, the results of current study show that there are difference morphometric characters in males and females. This situation may indicate that there is a difference in the growth of the characters mentioned in the female and male. The distinction between male and female is important for fisheries management, stock assessment, paleontological studies, population dynamics, and growth parameters. Furthermore, this study provides the first data on relationships between morphometric characters and total length in Wels catfish. These relationships are a helpful tool in predicting fish total length from morphometric characters and useful for studies on food and feeding, prey-predator relationships, as well as for paleontological studies.

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