Pakistan J. Zool., pp 1-8, 2024. DOI: https://dx.doi.org/10.17582/journal.pjz/20231125071011

Impact of Seasonal Variation on the Growth Dynamics of the Marine Catfish, *Arius maculatus* (Siluriformes: Ariidae) Collected from Karachi Fish Harbour

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Article Information
Received 25 November 2023
Revised 05 January 2024
Accepted 24 January 2024
Available online 23 April 2024 (early access)

Authors' Contribution
MA conceived the idea and wrote the manuscript. NA helped in experimental work. MA assisted in data analysis. AAK and HA evaluated the statistical data. MA revised the manuscript. FM and IZ reviewed and improved the manuscript, IDB and MNA helped in literature search, MS, supervised the work.

Key words
***Arius maculatus*, Growth dynamics, Marine catfish, Length-weight relationship, Condition factor, Spotted catfish**

ABSTRACT

Overfishing is the main cause of fish stock exploitation in the marine environment. In the current study growth dynamics of the marine catfish, *Arius maculatus* collected from Karachi Fish Harbour were studied. The relationship between total length and weight ($W=aL^b$) was significantly linear ($p<0.001$). The condition factor (K_f) varied from 1.06±0.12to 1.23±0.07. The 'b' values and R^2 values indicated that the growth was significantly ($p<0.001$) positive allometric ($b>3$) in the monsoons season while in the pre- and post-monsoon the growth was reported as significantly negative allometric ($b<3$). The negative allometric growth shows that the fish are unable to maintain their shape in the specific season. It is suggested to stop the fishing activities for marine catfishes during the spawning and oral incubation period in pre-monsoon especially from February to mid-April to ensure sustainable fishing with a better growth dynamic.

INTRODUCTION

Catfishes of the family Ariidae, vulnerable to overfishing have a long life, delayed maturation, single spawning season, low fecundity and oral incubation (Rimmer and Merrick, 1982; King and McFarlane, 2003; Winemiller, 2005). Especially these catfishes are vulnerable to overfishing (King and McFarlane, 2003; Winemiller, 2005). Catfish utilize a huge diversity of both plant and animal protein, and can adapt to unfavorable ecological conditions. Marine catfish tolerate a wide range of salinities between open sea and fresh water. They have soft scale less bodies, are greatly appreciated by consumers and maintain a healthy condition in both fresh and dried conditions (Amin *et al*., 2016).

Growth dynamics in fish populations could be calculated by length-weight relationship (LWR) parameters (Morato *et al*., 2001). According to Beyer (1987), LWR helps to understand a mathematical relation between the two variables of length and weight. The growth dynamic

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0030-9923/2024/0001-0001 $ 9.00/0

relationship is different among species because of their body shape and within species due to the condition of individual fish (Schneider *et al*., 2000). The condition factor is used to compare the condition, fatness or wellbeing of fish (Ahmed *et al*., 2011). LWR is an important tool for stock assessment, growth dynamic studies in fish population and for condition factor estimation (Abdurahiman *et al*., 2004; Dutta *et al*., 2012; Eagderi *et al*., 2020). Overfishing is among the major threats to fish depletion as the landing doubled in the last two decades, mostly due to the demands of alien fisheries (Dulvy *et al*., 2003; FAO, 2020a). Besides the financial worth of fisheries for numerous countries, fish is the dominant source of protein for human populations (FAO, 2020a). Relative body condition is an important indicator of the growth and reproduction of individuals or population (Gubiani *et al*., 2020; Jakob *et al*., 1996). Fish LWR parameters are important indicators for differentiation of taxonomic units and the changes in various progressive events such as metamorphosis, growth and maturity commencement (Mims and Knaub, 1993; Thomas *et al*., 2003; Alvarez- Lajonchère, 2012). It also increases the knowledge regarding commercially important fish natural history. Thus, making conservation possible as well as giving clues on climatic change impact in fisheries (Sarkar *et al*., 2013). The condition factor (K), is used to determine existing and upcoming population success by its influence on survival, growth and reproduction (Le Cren, 1951). Fulton's condition factor (K_f) is commonly used in the investigation of ontogenetic changes (Safran, 1992) and for life-history comparisons (Petrakis and Stergiou, 1995; Simon *et al*., 2009). Different values in K_f of a fish reveal the condition of sexual maturity, the level of food source accessibility, age, gender of various species (Anibeze, 2000). These relationships are also a necessary component of Fish Base (Froese and Pauly, 2012). The relative condition factor (*Kn*) introduced by le Cren (1951) balances for alterations in form or condition with length and could be applied to show whether an individual is in a better (*Kn*>1) or bad (*Kn*<1) state than a standard individual of the equal length.

The earlier studies on *Arius maculatus*, also known as spotted catfish, were mainly on the growth and food habitat (Mazlan *et al*., 2008). The current study aims to investigate the effects of seasonal variation on the growth dynamic of commercially important marine catfish *A. maculatus*. This study could help in sustainable fisheries management and provides the baseline for future study within the Arabian Sea.

MATERIALS AND METHODS

Study area

The chief fish harbor of Pakistan is Karachi Fish Harbour, which controls about 90% of fish and seafood catch in Pakistan (Pakissan.com, 2001-2007). The fishes samples were collected from Karachi Fish Harbour, West Wharf Karachi coast which is located at 66° 8′E longitude and 24°48′N latitude on the northeastern borderline of the Arabian Sea. Karachi has a temperate climate. The annual average temperature and rainfall are 21.15-30.78°C and 209.44mm, respectively. According to the Economic Survey of Pakistan, fisheries are the major source of livelihoods for many countryside communities inhabiting the coastline of Sindh and Baluchistan. Fish catch has decreased over the past two decades leading to poor socio-economy in the coastal areas of Pakistan. The Pakistan fish industry fetched 5.6 billion Rs in 2009-2010 and also employs 1 percent of the country's population and generates 1.3% of Pakistan's GDP (GOP, 2010).

Collection of material

Arius maculatus was seasonally (pre-monsoon, monsoon and post-monsoon) collected from Karachi Fish Harbour on weekly basis. Bottom trawls were used for catching the fishes off the shore and gill net was used to catch the fish in the coastal area in Arabian Sea. Specimens were identified with the assistance of FAO (Fischer and Whitehead, 1974) and Bianchi (1985) guidelines.

Length- weight relationship

Fish were sexed as male and female by observing the gonads. For each individual, total length (TL) was calculated from the lower jaw tip to the end of the caudal fin to the nearest 0.1 cm using a steel scale and whole-body weight (BW) was taken on a digital balance (Hytek) with 0.1 g accuracy. LWR were calculated by the formula of linear regression using Equation 1:

$Y=a+b*X$ …(1)

The LWR was estimated using the Equation 2:

$W= aTL^b$ (Ricker, 1973), …(2)

Where W is the derived weight, TL is total length (mm), a is the regression intercept curve and b is the regression coefficient. The length-weight relationship between males and females were calculated separately. When 'b' value is equal to 3 ($b=3$), the growth is isometric while the higher ($b>3$) and lower ($b<3$) values than 3 are called positive and negative allometric, respectively. The values of a and b were calculated by Equation 3. Student's t-test was applied to confirm the difference in significance of the isometric ($b=3$) b values.

$Log_{10} W= a + b \log_{10} TL$ ....(3)

Condition factor (K_f) and relative condition factor (Kn)

Condition factor (K_f) and relative condition factor (*Kn*) of the fish were calculated by the Equations 4 and 5, respectively:

$K_f = 100\times W/L3$ (Fulton, 1904) …(4)

Kn= W/aLb (Le Cren, 1951) …(5)

The values of *a* and *b* are taken from the logarithmic LWR equation.

Excel 2007 was used for data analysis and statistics. A *p*-value< 0.05 was considered significant.

RESULTS

During the study period, 204 male and 141 female of *A. maculatus* were collected. The highest number of the specimens were recorded in order monsoon (160) > post-monsoon (97) > pre-monsoon (88). In males the mean total length and weight were recorded as 40.23 ±0.39cm in monsoon and 37±0.23 cm in pre-monsoon and 794.9±18.2 g in monsoon and 566.6±4.6 g in pre-monsoon, respectively. In female the maximum total length (41±0.41 cm) and weight (807.12±14.55 g) were obtained in monsoon and post-monsoon season, respectively. The lowest mean total length (33.55±0.504 cm) and weight (596±16 g) were measured in pre-monsoon (Table I).

The overall allometric coefficient *b* for LWR in the entire three seasons for combined sexes (Fig. 1) indicated negative allometric growth ($b<3$) and coefficient of determination (R^2) was reported as significant (<0.5) ($LogW$ =-0.709+2.23TL, r^2= 0.701). Fulton condition factor ($K_f = 100\times W/L^3$) for overall data was 2.310. The highest (1.2) and the lowest (1.06) K_f ($K_f = 100\times W/L^3$) were recorded during monsoon in male and female, respectively (Fig. 2).

The growth of male specimens in pre-monsoon was negatively allometric ($W = 1.04\times TL^{1.08}$and R^2 = 0.902). The Student's t-test indicated a highly significant changes as the slope is different from the slope of 3 (t= - 241.12**, p<0.001) (Fig. 3A, Table II). The growth of female specimens in pre-monsoon was also negatively allometric ($W = 0.50\times TL^{2.07}$and R^2 = 0.834). The Student's t test indicated a highly significant changes as the slope is different from the theoretical slope of 3 (t= 78.40**, p<0.001) (Fig. 3B, Table II).

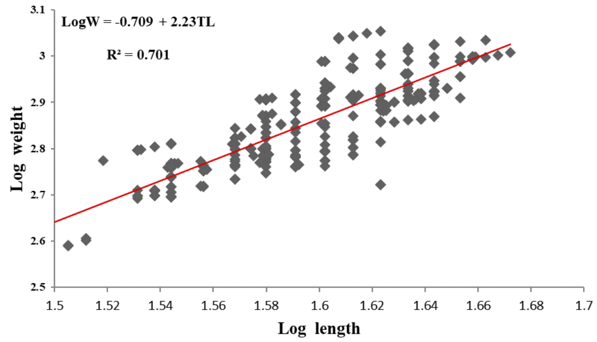

Fig. 1. Length/weight relationship in combined sex of *A. maculatus.*

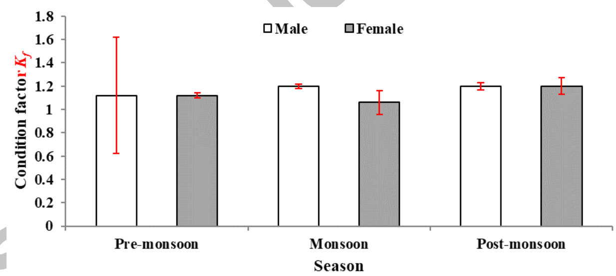

Fig. 2. Condition factor (K_f) of *A. maculatus* in different season.

The growth of *A. maculatus* male in monsoon was positive allometric as its '*b*' value was found to be 3.22 and the LWR was $W = 2.35\times TL^{3.22}$ (Fig. 4A, Table II). The R^2 value was 0.329. The Student's t test (102** p<0.001) indicated a highly significant change in LWR. The growth of female in monsoon was reported as negatively allometric ($W = 0.5\times TL^{2.1}$ and R^2 = 0.853) with a highly significance in-test (75.88**, p<0.001) (Fig. 4B, Table II). The growth of *A. maculatus* male in post-monsoon was $W= 1.13\times TL^{2.25}$ and R^2= 0.754 (Fig. 5A) where the '*b*' value was 2.945, the R^2 value was 0.9923 so the growth indicated

Table I. Seasonal variation in growth indices of male and female marine catfish, *A. maculatus*.

	Pre-Monsoon				Monsoon				Post-Monsoon			
	Male (n=48)		Female (n=40)		Male (n=90)		Female (n=70)		Male (n=66)		Female (n=31)	
	TL (cm)	W (g)	TL (cm)	W (g)	TL (cm)	W (g)	TL (cm)	W (g)	TL (cm)	W (g)	TL (cm)	W (g)
Min-Max.	34-42	495-615	31.5-42	378-716	34-45.65	512-1133	34-47	492-1016	33-46	576-1082	37-45	695-960
Mean±S.E.	37± 0.23	566.6± 4.65	33.8± 0.504	596.8± 16	40.2± 0.39	794.9± 18.23	41± 0.41	741.7± 17.55	39.2± 0.32	774.6± 20	40.8± 0.55	801.75± 14.55

N, sample size; TL, total length; W, weight; g, gram; Min, minimum; Max, maximum; S.E., standard error.

Table II. Length-Weight relationships (log_{10} transformed) of male and female marine catfish *A. maculatus*.

Equation W=a + b × TL	Pre-Monsoon		Monsoon		Post-Monsoon	
	Male	Female	Male	Female	Male	Female
a	1.04	-0.50	2.34	0.56	1.12	5.45
S.E. (a)	0.23	0.236	0.95	0.24	0.39	0.32
b	1.08	2.07	3.23	2.12	2.55	1.55
S.E. (b)	0.146	0.15	0.58	0.25	0.24	0.20
R^2	0.555	0.834	0.32	0.857	0.75	0.74
Mean K_f ± S.E.	1.124±0.5	1.12±0.02	1.2±.02	1.06±0.12	1.2±0.03	1.2±0.07
Mean Kn ± S.E.	00	0.833±0.01	00	0.6±0.01	0.06±0.001	0.59±0.02
t-test	-241.1**	78.40**	102**	75.8**	81.8**	105.1**
p-value	0.001	0.001	0.001	0.001	0.001	0.001

a, intercept; *b*, slope; R^2, coefficient of determination; **, highly significant; K_f represent Fulton; *Kn*, relative condition factors; $p<0.05$ significant; $p<0.001$ highly significant.

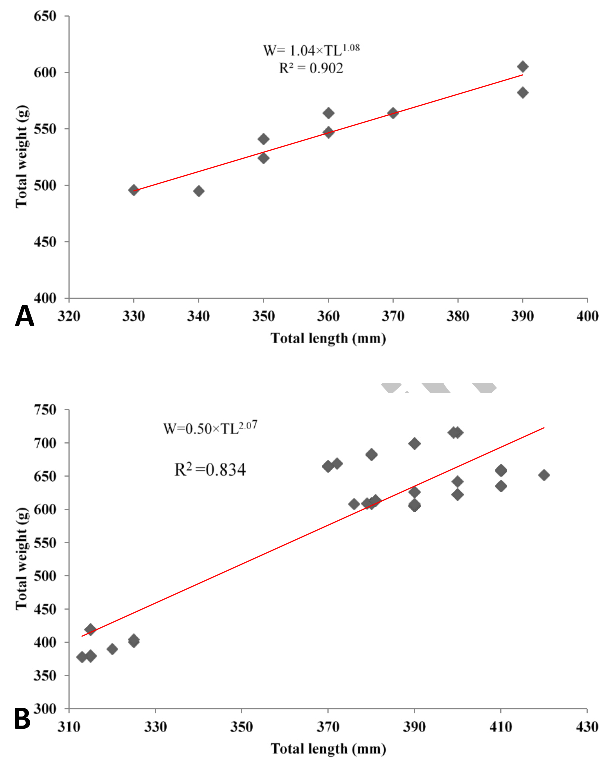

Fig. 3. Length weight relationship of male (A) and female (B) *A. maculatus* in pre-monsoon.

negative allometric. The t test was found highly significant as 81.88** where p<0.001 (Table II). In post-monsoon season the growth in female specimens was noted as negatively allometric (W= 5.44×$TL^{1.55}$and R^2 = 0.787) with a highly significant t-test (105.12**, p<0.001) (Fig. 5B, Table II). The relative condition factor (*Kn*) was recorded in females only where the highest value was recorded in pre-monsoon (0.833±0.01) followed by monsoon (0.6±0.01) and then post-monsoon (0.59±0.02) (Table II).

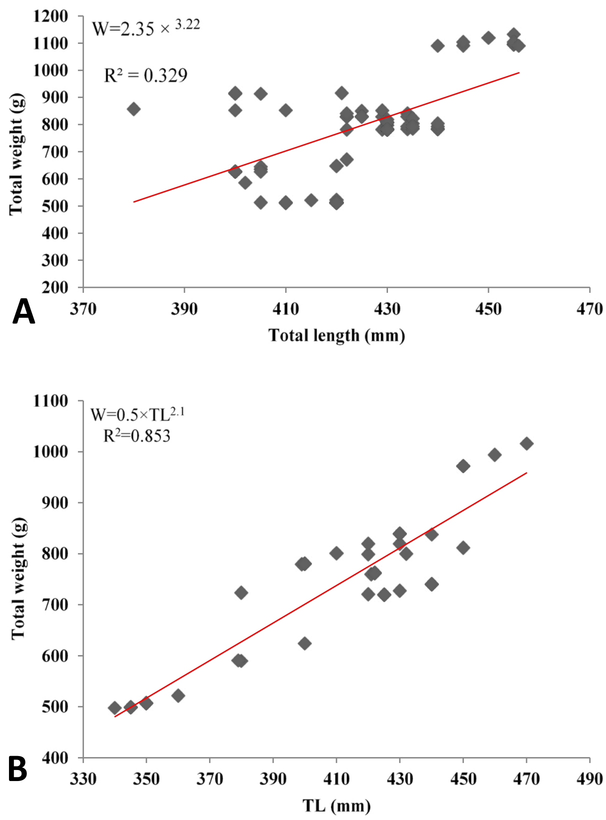

Fig. 4. Length weight relationship of male (A) and female (B) *A. maculatus* in monsoon.

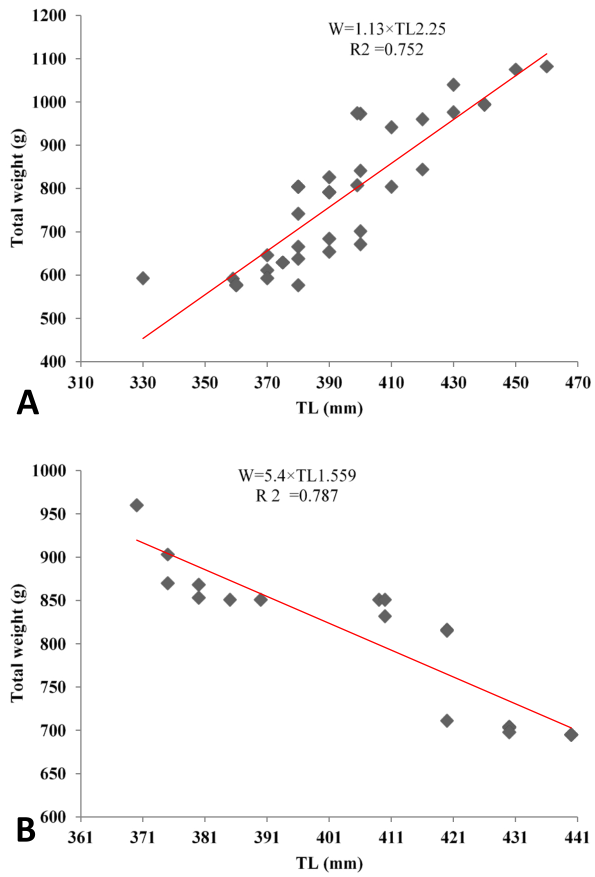

Fig. 5. Length weight relationship of male (A) and female (B) *A. maculatus* in post-monsoon.

DISCUSSION

The current results indicated a linear relationship of increase in weight with length, however, this ratio shows variation in various fish species, habitat, health condition, water temperature and food (Le Cren, 1951; Hossain and Ohtomi, 2010). The *b* value was used in the length-weight relationship (LWR) as the indicator of growth. The value of LWR (*b*) close to 3 indicates isometric growth, but its higher (*b*>3) and lower (b<3) values than 3 indicate positive and negative allometric growth, respectively (Tesch *et al*., 1971). In the current study, the highest and lowest significant (p<0.001) *b* values were reported during monsoon and pre-monsoon in male, respectively. The combined overall b value in the entire season was also reported as negative allomeric (2.32). Similar results where *b* value is 1 (pre-monsoon, 1.79; monsoon, 1.07; post-monsoon, 1.13; overall, 1.11) were also reported by Muzaffar *et al*. (2020) in *Rastrelliger kanagurta*. Chu *et al*. (2012) reported in *A. maculatus*, a significant highest b value (b=3.04) in monsoon and the lowest (*b*=2.83) in post-monsoon. Our findings also support the study of Chu *et al*. (2012). The *b* values of the different catfish species, *Arius gagora*, *Neutoma caelatus*, *A. tenuispinis*, *Osteogeneiosus militaris* had shown positive allometry and *Neutoma bilineata*, *A. dussumieri* and *Neutoma thalassina* were indicating negative allometry. The *b* values above isometric (*b=3*) of large specimens are the result of increase in girth (Froese, 2006). The *b* values for *A. dussumieri* and *Arius caelatus* reported by Dutta and Hazra (2013) and from West Bengal Froese (2006) were close to the current findings of *A. maculatus*. The allometric growth in *b* values depend on several factors such as sex, gonad maturity, physiology, season, habitat, food, stomach fullness, length frequency and fishing gear (Tesch, 1968; Gayanilo and Pauly, 1997; De Giosa *et al*., 2014; Eduardo *et al*., 2019, 2020a; Grimaldo *et al*., 2020; Slayden, 2020; López-Pérez*et al*., 2020). Thus, the negative and positive allometric growth in fishes indicate poor habitat conditions and optimum habitat conditions, respectively (Abowei, 2010).

In this study the coefficient of determination (R^2) is between 0.32 (male) to 0.859 (female) in monsoon. The high R^2 (r^2 >0.5) values indicate good growth rate and less than 0.5 shows growth rate is abnormal (Afsarullah *et al*., 2015).

K_f indicates the plumpness, maturity and spawning gonadal development and general fitness of the fish (Wootton, 1990). Condition factor of *A. maculatus* in the current study is between 1.23±.02 (male) to 1.06±0 (female) in monsoon season. However, the K_f factor of fish can be affected by some factors such as stress, gender, season, nutrition and other ecological parameters (Khallaf *et al*., 2003).

Relative condition factor (*Kn*) of the current study indicated that the highest *Kn* value was reported in pre-monsoon (0.833±0.01) and the lowest in post-monsoon (0.59±0.02) (Table II). Higher *Kn* values indicate that the fish in good condition. Vazzoler (1996) reported that the lowest *K* values during the mature gonad stages indicated that the resource had been transferred to the gonads during the reproduction cycle. The present maximum *Kn* value in pre-monsoon indicated contradiction with reports of Twilley (1988) and Harrison *et al*. (1997) as per their study higher condition factor was expected during the monsoon, due Northeast monsoon winds increased primary productivity in Arabian Sea. Lower fishing pressure could cause negative allometric growth while the positive allometric growth is the consequence of excessive fishing pressure (Bilgin and Solak, 2020).

CONCLUSION

This study provides baseline information on the growth of marine catfish, *A. maculatus* from the Arabian Sea. Moreover, the LWR of this commercially important fish provide information for stock assessment and sustainable fisheries management. This work has also highlighted positive and negative allometric growth in natural habitat of this species.

ACKNOWLEDGEMENT

I gratefully acknowledge the help of my father named Muhammad Zaman Khan who provided me the samples and helped in fish identification.

Funding

Department of Zoology, University of Karachi, Karachi, Pakistan provided funds and logistics for this study.

Statement of conflict of interest

The authors have declared no conflict of interest.

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