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Length-weight relationship and seasonal effects of the Summer Monsoon on condition factor of *Terapon jarbua* (Forsskål, 1775) from the wider Gulf of Aden including Socotra Island

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Abstract

The present study investigates the length-weight relationship and the condition factor of populations of the Indo-Pacific fish *Terapon jarbua* (Forsskål, 1775) collected in the wider Gulf of Aden, notably from Socotra Island and the Hadramout coast of Yemen. This region displays a monsoon climate, with wide seasonal variation affecting estuarine habitats. A total of 620 specimens collected in estuaries and at sea were measured and weighted during field surveys carried out in 2007 and 2008 during pre- and post- South-Western monsoon periods. The length-weight relationship of the studied populations of *Terapon jarbua* is determined as $W = 0.0288 \times SL^{2.99}$, with $r^2 = 0.96$ and is consistent with existing data on the species from other regions. Significant seasonal differences were found in Fulton's condition factor of *Terapon jarbua*.

Keywords: *Terapon jarbua*, length-weight relationship, condition factor, monsoon, Gulf of Aden, Socotra Island

Introduction

The grunter *Terapon jarbua* (Terapontidae, Perciformes) locally known as "Dirhar" in Yemen mainland and "Habraham" on Socotra Island, inhabits marine and brackish waters of the Indo-West Pacific (Klausewitz and Nielsen, 1965; Nielsen, 1974; Vari, 1978) and the Eastern Mediterranean (Golani and Appelbaum-Golani, 2010). Estimates on length-weight relationships (LWR) for this species have been reported from populations in Thailand (Yanagawa, 1994), Indonesia (Pauly et al., 1996), New Caledonia (Kulbicki et al. 2005; Letourneur et al., 1998), South Africa (Harrison, 2001) and China (Zhang et al., 2002).

The climate of the studied region is characterized by the alternating monsoon seasons in the Northern Indian Ocean driven by the Inter-Tropical Convergence Zone (ITCZ). From October to February the weaker Winter or North-East Monsoon dominates with a rainy period starting in October and being strongest in November/December. From April/May to September the forceful Summer or South-West Monsoon blows strong hot winds that generate upwelling of cold nutrient-rich waters on both the North and South coasts of Socotra, and on the South coast of Yemen mainland (Fleitmann et al., 2004; Fratantoni et al., 2006; Klaus and Turner, 2004; Scholte and De Geest, 2010). The objective of the present study is to compare LWR of *Terapon jarbua* from the wider Gulf of Aden region with that from other regions and to assess seasonal effects of the Summer Monsoon on Fulton's condition factor K (Froese, 2006; Muchlisin et al., 2010; Pauly, 1984).

Materials and methods

Sampling and measurements

620 specimens of *Terapon jarbua* were sampled using a 30 m seine net (10 mm mesh size) at different locations in the wider Gulf of Aden region including Socotra Island and the Hadramout coast of Yemen from 2007 to 2008 during pre- and post- South-Western monsoon periods. The Standard Length (SL) of all observed specimens ranged from 4.7 to 27.9 cm, with a mean value of 8.7 cm. All specimens were measured to the nearest 0.1 cm and weighed (W) to the nearest gramme.

Length-weight relationship

The sex was not differentiated in this study. Although most of the samples were juveniles it is appreciated that sex may have affected the LWR. The LWR was determined by the equation $W = a \times SL^b$. Both parameters a and b were estimated by ordinary least squares regression through a logarithmic transformation of the data: $log(W) = log(a) + b \times log(SL)$ where $log(a)$

is the intercept and *b* the slope of the regression line (Clark, 1928; Froese, 2006; Keys, 1928; Kulbicki et al., 2005). The hypothesis of isometric growth was tested by Student's *t*-test. To compare the estimates found in this study with those reported by other authors in different areas of the Indo-Pacific region (Table 1), Froese (2006) proposed to correct parameter *a* by applying the following formula: $a' = a \times 10^b$ (from data in mm and g to data in cm and g).

Fulton's condition factor

The Fulton's condition factor was calculated for each individual fish according to the equation: $K = 100 \times W \times SL^{-3}$ (Froese, 2006; Muchlisin et al., 2010; Pauly, 1984), and since $b = 2.99$ close to 3, condition factor could be compared for different length (Froese, 2006). As the hypotheses of normality (Shapiro and Wilk, 1965) and homoscedasticity (Bartlett, 1937) were not met for all populations ($p < 0.05$), differences in K were investigated using Kruskal-Wallis tests (Kruskal and Wallis, 1952). Due to time restrictions and site access denied by some local village authorities, seasonal comparison was only possible for Khor Dubena (Khor = estuary or coastal lagoon) and spatial comparison was only possible for the pre-monsoon periods. Additionally Nemenyi-Damico-Wolfe-Dunn post-hoc tests (Hollander and Wolfe, 1999) were performed to identify among which seasons and among which locations differences occur. All statistical analyses were performed using the function *shapiro.test*, *bartlett.test* and *kruskal.test* of the R package *stat*s and the function *oneway_test* of the R package *coin* (Ihaka and Gentleman, 1996).

Results and discussion

Length-weight relationship

The LWR of *Terapon jarbua* is $W = 0.0288 \times SL^{2.99}$, with $r^2 = 0.96$ as represented in Fig. 1. Descriptive statistics and estimated LWR parameters of *T. jarbua* from this study and from other studies are summarized in Table 1. The value of the parameter *b* in the present study was not significantly different from three ($t = -0.314$, $p > 0.05$); therefore the hypothesis of isometric growth for *T. jarbua* in the wider Gulf of Aden was not rejected (Froese, 2006; Giacalone et al., 2010; Harrison, 2001). Different types of length measurements (Standard Length, Total Length and Fork Length) used by the different authors might have altered the estimation of parameter *a* but not *b* (Froese, 2006). In order, however, to compare the estimates found in this study with other authors' estimates, the *log*(*a*) was plotted against *b* (Fig. 2) and proved to be consistent with existing data for *Terapon jarbua*.

Fulton's condition factor

The values for K ranged from 1.399 to 4.523. At Khor Dubna, significant differences in K between pre- and post-monsoon samples in 2007 and 2008 ($p < 0.01$) were found with K mean values higher during the post-monsoon than the pre-monsoon periods. No difference was found between years (Fig. 3). Seasonal changes in body weight and in protein, lipid and water contents in fishes as been reported in several studies (Weatherley and Gill, 1987) and is usually driven by the food availability, the environmental conditions and the reproductive status of the fishes; this last parameter being not considered in the data mainly measured on juveniles. The high K values during the post- Summer Monsoon period are the direct consequences of the upwelling responsible of higher productivity and food availability. Indeed upwelling systems of cold nutrient-rich waters are formed, promoting high primary and secondary productivity (Klaus and Turner, 2004). Strong coastal wind and wave action establish connections between estuaries and the fertile ocean water masses which are otherwise often partly or fully isolated from each other. Thus, the high availability of nutrition, and the favorable environmental conditions during the South-West Monsoon (e.g.: lower water temperatures and salinity, higher oxygenation levels) allow fishes to increase in weight in a short period of time. By contrast the low K values during the pre- Summer Monsoon period can be explained by the degradation of environmental conditions (e.g.: higher water temperatures and salinity up to 39 ‰, lower oxygenation levels) and nutritional impoverishment in the estuaries.

The null hypothesis of no differences between fish condition factors during the same season at different locations could not be rejected for most locations. However, two locations Khor Dubena and Khor Bidholeh both located on Socotra Island were significantly different in K ($p < 0.01$) than all other locations (Fig. 4). The low K values of *T. jarbua* individuals at Khor Dubena can probably be explained (1) by the high fish diversity (27 species) inducing a high inter-specific competition for food and (2) by the high abundance of large predators such as the jack *Caranx heberi* (Bennett, 1830), the snappers *Lutjanus argentimaculatus* (Forsskål, 1775) and *Lutjanus fulviflamma* (Forsskål, 1775) and the emperor *Lethrinus nebulosus* (Forsskål, 1775). Moreover this estuary is often closed from the sea for several months with only occasional water exchange with the ocean thus further reducing food availability for *T. jarbua* during these periods. The high K values at Khor Bidholeh could be related to the presence of a small fish landing site. Indeed, fish wastes have been observed as being directly discarded into the estuary and could represent a non negligible source of food for *T. jarbua* which constitute the dominant species of this estuary.

Terapon jarbua is a temporal resident of coastal estuaries in the study area and occasionally targeted in the local subsistence fisheries. More generally, over the Indo-West Pacific, juveniles of *T. jarbua* are abundant in brackish waters as in the mangroves of Madagascar (Laroche et al., 1997), where this species represent 16% of the catch (i.e.: the second rank after the Gerreidae). The present study provides basic information on the LWR and seasonal condition of *T. jarbua* populations in the wider Gulf of Aden region in support of sustainable management of the species and especially of the estuaries of the coasts of Socotra Island and the Hadramout, Yemen.

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Table 1: Descriptive statistics and estimated parameters of length-weight relationships for *Terapon jarbua*

		Length (cm)			LWR Parameters				
	n	**Min**	**Max**		***A***	***a* Cl 95%**	***b***	***b* Cl 95%**	**r^2**
Present study	**620**	**4.7**	**27.9**	**SL**	**0.0288**	**0.0262- 0.0318**	**2.99**	**2.95- 3.04**	**0.96**
Kulbicki et al. 2005 *	87	2.0	28.5	FL	0.0132	-	3.13	-	0.98
Zhang et al. 2002 *	-	-	-	-	0.0389	-	2.87	-	-
Harrison 2001**	70	1.0	14.8	SL	0.0340	-	2.94	-	0.99
Letourneur et al. 1998 *	97	2.0	28.5	FL	0.0154	-	3.08	-	0.98
Pauly et al. 1996*	-	8.0	19.0	FL	0.0748	-	2.52	-	0.98
Yanagawa 1994 *	6	9.6	26.8	TL	0.0222	-	2.88	-	0.99

n, sample size; Min, minimum; Max, maximum; FL, Fork Length; SL, Standard Length; TL, Total Length

* Data collected from FishBase (Froese and Pauly, 2011)

** Original length was in mm and weight in g, parameter *a* was corrected using the following equation: $a' = a \times 10^b$ (Froese, 2006)

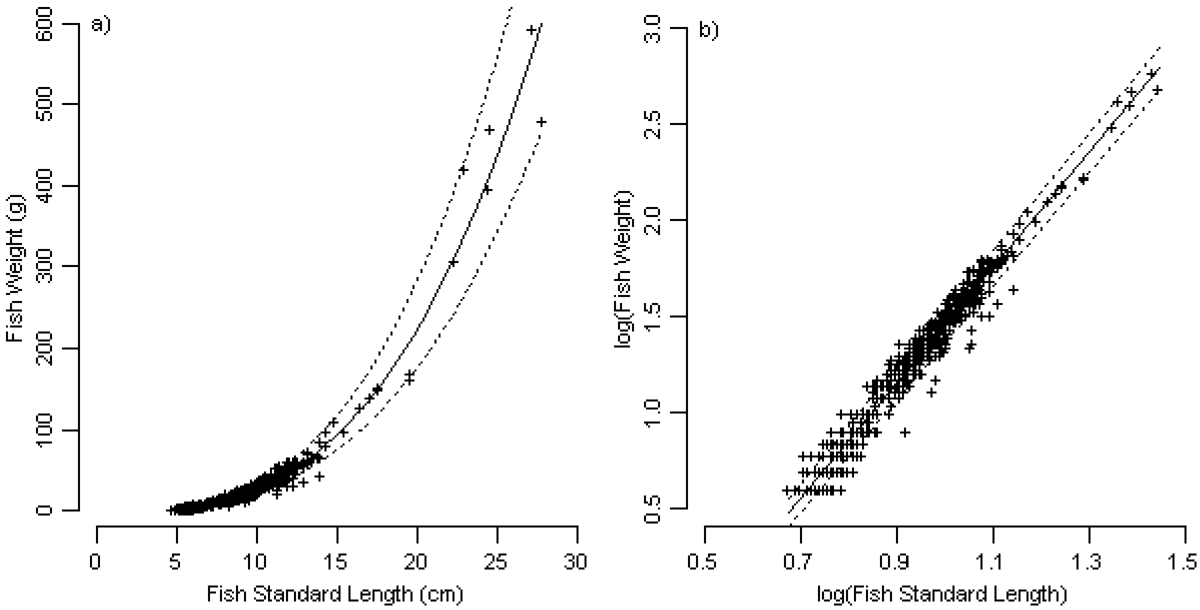

Figure 1: Length-weight relationship of *Terapon jarbua* from the wider Gulf of Aden

a) Regression of Fish Standard Length *vs*. Fish Weight, the plain curve represents the LWR regression curve $W = 0.0288 \times SL^{2.99}$, $r^2 = 0.96$ and the dotted curves represent the upper and lower 95 % confidence limits of the LWR Regression curve. b) Linear regression of the log transformed data presented in a).

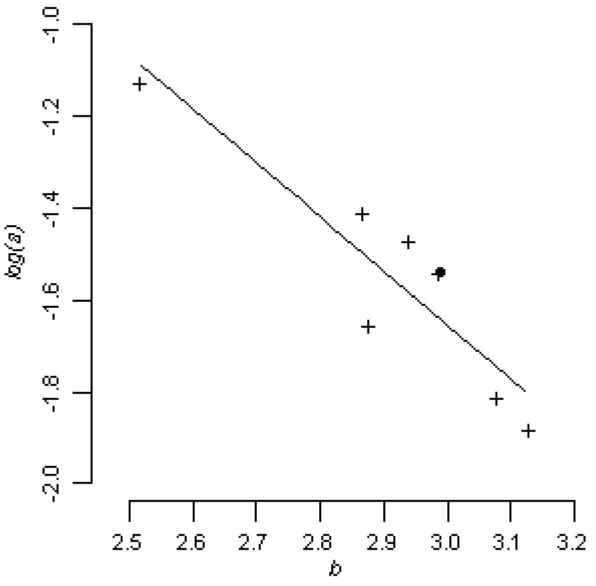

Figure 2: Test plot of *log*(*a*) against *b* for seven LWRs of *Terapon jarbua*
The black dot identifies the present study parameters. The crosses represent the parameters of the six other studies (Table 1). The plain line represents the regression line, $r^2 = 0.84$. The extreme point on the left might be seen as an outlier, possibly because it includes a narrow range of juveniles

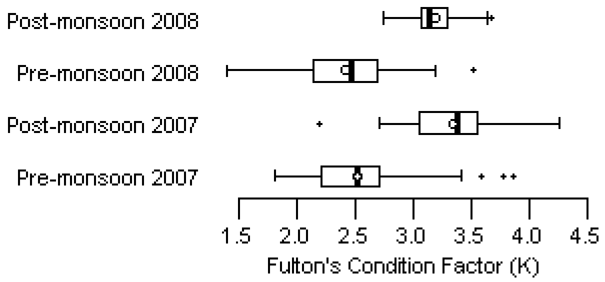

Figure 3: Box plot of condition factor K for Khor Dubena during pre- and post- Summer Monsoon periods of 2007 and 2008

The open circles represent the mean condition factor, the vertical dark bars represent the median condition factor, boxes encompass 50 % of the data, whiskers encompass 95 % and small crosses represent outliers. Only differences between seasons are significant ($p < 0.01$).

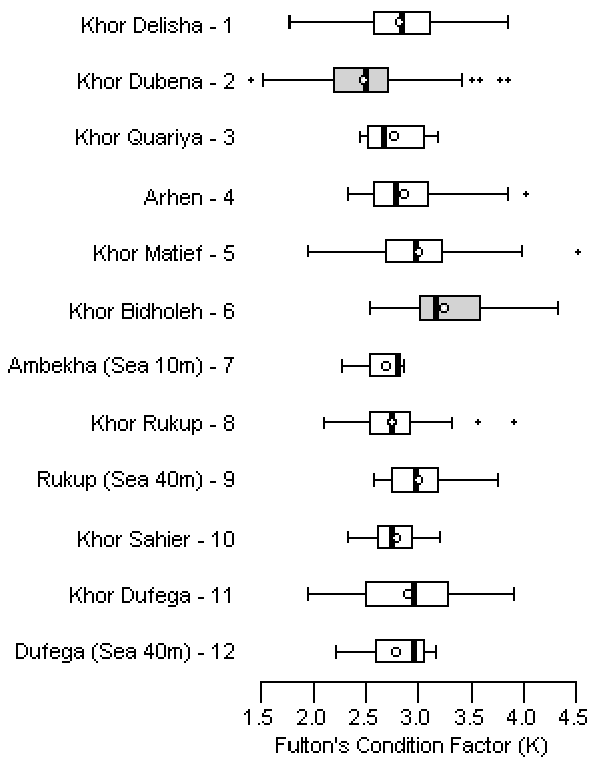

Figure 4: Box plot of condition factor K per locations during pre- Summer Monsoon periods
The open circles represent the mean condition factor, the vertical dark bars represent the median condition factor, boxes encompass 50 % of the data, whiskers encompass 95 % and small crosses represent outliers. The light grey boxes represent the locations that are significantly different ($p < 0.01$) from all other locations.