BIOMETRIC RELATIONS OF WILD AND FATTENED *THUNNUS THYNNUS* (L. 1758) CAUGHT OFFSHORE TUNISIA (IONIAN SEA, CENTRAL MEDITERRANEAN) IN 2012

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SUMMARY

This work describes length–length (LLR) and length–weight (LWR) relationships of wild and fattened bluefin tuna (BFT), Thunnus thynnus*, caught offshore Tunisian southern coasts (Ionian Sea, Central Mediterranean). Fulton's condition factor (K) was also estimated. A total of 170 wild and 473 fattened fishes were sampled. Both fish groups were caught by purse-seine in summer 2012. The LLRs, the LWRs and the condition factor K showed a significant differences between wild and fattened fishes for the relations: CFL = a + b FL ; LD1 = a + b FL and TW = a FLb and the average of K. However, there were no significant differences in the LLRs and LWR for wild fishes between males and females.*

RÉSUMÉ

Ce travail décrit les relations longueur-longueur (LLR) et longueur-poids (LWR) du thon rouge Thunnus thynnus*, sauvage et engraissé. Les poissons ont été pêchés par les senneurs au large des côtes tunisiennes (Mer Ionienne, Méditerranée Centrale) en été 2012. Le facteur de condition K (Fulton) a été aussi estimé. Au total 170 poissons sauvages et 473 engraissés ont été échantillonnés. Les relations LLR et LRW et le facteur de condition K ont montré des différences significatives entre les poissons sauvages et ceux engraissés pour les relations CFL = a + b FL ; LD1 = a + b FL et TW = a FLb et le facteur de condition K. Cependant, il n'y a pas de différence significative, pour toutes les relations LLR et LWR et pour K, entre les mâles et les femelles des poissons sauvages.*

RESUMEN

Este trabajo describe las relaciones talla-talla (LLR) y talla-peso (LWR) de atún rojo (BFT), Thunnus thynnus*, salvaje y engordado, capturado en aguas de las costas meridionales de Túnez (mar Jónico, Mediterráneo central). Se estimó también el factor de condición (K) de Fulton. Se muestreó un total de 170 ejemplares salvajes y 473 engordados. Ambos grupos de peces fueron capturados mediante el cerco en el verano de 2012. Las LLR, LWR y el factor de condición K mostraban diferencias significativas entre los peces salvajes y los engordados para las relaciones: CFL = a + b FL; LD1 = a + b FL y TW = a FLb y la media de K. Sin embargo, no había diferencias significativas en las relaciones LLR y LWR ni para K entre las hembras y los machos de los peces salvajes.*

KEYWORDS

Thunnus thunnus, Length-length relationships, Length-weight relationships, Condition factor

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1. Introduction

Following ICCAT recommendations to improve knowledge of bluefin tuna *Thunnus thynnus* (BFT) caught in the Mediterranean Sea sampling was carried out to determinate length-weight and length-length relationships. The later relationships are key parameters used in the stock assessment.

It is known that some morphometric length-length (LLR) and length-weight relationships (LWR) in fish may change as a function of environmental conditions and/or physiological status (Weatherley and Gill, 1987). Since growth, feeding and mobility inevitably differ substantially in wild and fattening conditions.

The aims of this study were to give information on LLRs, LWR sand on the condition factor for the BFT caught offshore the Tunisia coasts (Ionian Sea, Central Mediterranean) and we attempt to ascertain differences between sexes for wild fishes and before and after the fattening process.

2. Material and methods

2.1 Samples

The bluefin tuna sampled were captured by purse seine in the Ionian Sea (Central Mediterranean), offshore Tunisian southern coasts, in June 2012. The wild fishes (N = 170) were sampled onboard during catching and transfer. From this group of fishes we identified 33 males and 37 females. The fattened specimens (N = 473) were sampled from the 09th November to the 08th December 2012 in a tuna farm located in Mahdia (Tunisia)onboard immediately after slaughter. The later were fattened during 5-6 months.

2.2 Parameters

Lengths were measured with a 3-m slide gauge to the nearest centimetre, and weight measured with a digital force gauge to the nearest kilogram. The following parameters were estimated TL: Total Length, FL: Fork Length, CFL: Curved Fork Length, LD1: Head to the First Dorsal Spine Length and TW: Total round Weight.

2.3 Relationships and equations

FL of fishes were arranged in the interval of 10 cm to elaborate the size frequencies. The length–length relationships (LLR) are described by the equation:

$$L_1 = a + bL_2$$

where L_1 and L_2 are lengths, a and b are constants (intercept and slope, respectively).The length–weight relationships (LWR) have the equation:

$$TW = a\ FL^b$$

To get the linear equation data were log-transformed,

$$\log(TW) = \log a + b \log FL$$

where a and b are constants (intercept and slope, respectively).The parameters of the LLR and LWR, a and b, the coefficient of determination R^2 and the standard deviations (S.D.) were estimated by least squares regression and tested by the Student's t test (Zar, 2010).

To test the isometric of the relative growth in LLR (b = 1) and LWR (b = 3) the Student's t-test was applied (Sokal and Rohlf, 1995).The significant differences (p = 0.05) of slopes (b) and intercepts (a) of the LLR and LWR between wild and fattened fishes and between wild males and females was performed by the ANCOVA analysis (Zar, 2010).

The Fulton's condition factor (K) was estimated according to the following equation (Froese, 2006):

$$K = 10^5 TW / FL^3$$

where TW is the total round weight in kg of the fish and FL the fork length in cm. To compare the mean k between wild and fattened fishes the Student's t-test was performed (Zar, 2010).

Statistical analysis and graphs were performed with STATISTICA Software (Statsoft Inc, version 7.1).

3. Results

3.1 Summary on data and size frequencies

A total of 643 BFT fishes were sampled during the study, 170 were wild and 473 were fattened (**Table 1**). For wild fishes fork length (FL) were between 114 and 242 cm with an average of 141.92 ±28.19 cm. The total round weight (TW) for this group was between 28.5 and 268 kg with an average of 58.38 ± 42.50 kg. The mean lengths for wild males and females were 143.79 ±38.23 cm and 161.05 ± 61.56 cm, respectively.

FL of fattened fishes had the minimum of 120 cm and the maximum of 274 cm with an average of 208.61 ± 33.43 cm. The TW was between 35 and 485 kg, with an average of 201.56 kg.

Length-frequency for wild fishes indicated that the 120 and 130 cm length classes had the highest proportions, 39% and 28%, respectively (**Figure 1**). Big fishes had the mode of 210 cm. However, for the fattened fishes the classes 210 cm and 220 cm were dominant with proportions of 19% and 25%, respectively (**Figure 2**). We note the presence of the mode 140 cm for smaller fishes.

3.2 Length-length relations

All LLRs shown in **Table 2** were highly significant (test of Student, $p< 0.01$), with the coefficient of determination values being $R^2>0.94$.For both groups of fishes, the LLRs: FL and TL; FL and CFL showed positive allometry and the LLR: FL and LD1 negative allometry. The ANCOVA showed significant difference only for the intercepts (a) in the LLR (CFL = a + b FL/ and LD1 = a + b FL) between the two groups of fishes (**Table 4**).

For wild fishes LLRs, we note for males isometry between FL and CFL. The relations FL-TL and FL-LD1 show the same allometry for both sexes. The test of significant difference for the intercepts and slopes (LLRs and LWRs) showed no difference between sexes.

3.3 Length-weight relations

The LWRs showed a highly significant (t-test, $p < 0.001$), for wild and fattened fishes with the coefficients of determination $R^2 = 0.95$ and $R^2 =0.97$, respectively. The calculated coefficients b were 2.7897, for wild fishes with negative allometry and 3.0156, for fattened fishes with isometric allometry (**Table 3**). The ANCOVA showed significant difference of the LWR (for intercepts a and slopes b) between the two groups of fish (**Table 4**, **Figure 3**).

In the wild fishes, the LWR allometries were negative for males and isometric for females.

3.4 Condition factors

Fulton's condition factor (K) in relation to size class is indicated in **Figure 4**. K lower values were 1.58 (class 200 cm) in wild fishes and 1.93 (class 190 cm) in fattened fishes. The higher condition values of wild and fattened were for the classes 110 cm (K = 1.99) and 260 cm (K = 2.34), respectively. Average K values in wild and fattened were 1.85 ± 0.21 and 2.07 ± 0.18, respectively. There was a significant difference in K (t-test, $p< 0.01$) between wild and fattened fishes.

However, there wasn't a significant difference for the condition factor between the wild males (K = 1.87± 0.23) and wild females (K = 1.90 ± 0.20) (t-test p = 0.54).

4. Discussion

The LLRs, the LWRs and the condition factor K showed a significant differences between wild and fattened fishes for the relations: CFL = a + b FL; LD1 = a + b FL and TW = a FL^b and the average of K. The three parameters CFL, LD1 and K are known to increase under the influence of the fattened process (Aguado-Gimenez, and García-García, 2005b). However, there were no significant differences in the LLRs and LWR for wild fishes between males and females.

We note that there were no significant differences in the condition factor (K) between males and females. This is in agreement with the result of Percin and Akyol (2009).

It's known that the parameters of LWR in fish are affected by a series of factors such as habitat, gonad maturity, sex, feeding and the annual differences in environmental conditions (Froese, 2006). Various authors have also reported differences in the LLW relationships of BFT caught or fattened in the Mediterranean (**Table 5**).

In conclusion, this paper provides basic and updated information on LWRs, LLRs and K for BFT species, caught offshore Tunisian waters (Ionian Sea) useful for fishery biologists and management authorities in the Mediterranean. We note the effect, of the fattened process on the different relations and on the condition factor.

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Table 1. Summary of the observed values for wild and fattened bluefin tuna (S.D. standard deviation).

	Variable	*n*	*min*	*mean*	*max*	*SD*
Wild	TL	170	124	152.976	258	29.748
	FL	170	114	141.929	242	28.189
	CFL	170	118	146.547	252	29.102
	LD1	170	34	42.870	68	7.308
	TW	170	28.5	58.385	262	42.502
	K	170	1.434	1.851	2.499	0.201
Wild ♂	TL	33	125	155.061	258	41.06
	FL	33	114	143.788	242	38.226
	CFL	33	119	147.909	252	38.954
	LD1	33	35	42.939	66	9.682
	TW	33	28.5	66.150	262	61.560
	K	33	1.466	1.871	2.499	0.207
Wild ♀	TL	37	124	161.054	247	39.039
	FL	37	116	150.081	233	37.099
	CFL	37	118	155.243	242	39.225
	LD1	37	35	44.865	68	9.889
	TW	37	30	74.447	217	57.862
	K	37	1.458	1.903	2.429	0.233
Fattened	TL	473	127	223.486	290	35.255
	FL	473	120	208.615	274	33.432
	CFL	427	125	215.911	283	36.023
	LD1	427	26	60.386	77	9.107
	TW	473	35.0	201.564	485	80.958
	K	473	1.469	2.069	2.953	0.176

Table 2. Parameters of the LLRs and LLWs for wild and fattened bluefin tuna (**: $p<0.01$).

	X=FL/ Y=	*a*	*b*	*SEa*	*SEb*	R^2	*p*
Wild	TL	3.850	1.051	1.101	0.008	0.99	**
	CFL	0.596	1.028	1.023	0.007	0.99	**
	LD1	7.104	0.252	0.681	0.005	0.94	**
	TW	$5.2\ 10^{-5}$	2.790	0.000	0.047	0.95	**
Wild♂	TL	1.001	1.071	2.051	0.014	0.99	**
	CFL	1.658	1.017	1.710	0.011	0.99	**
	LD1	6.892	0.251	0.968	0.006	0.98	**
	TW	$4.4\ 10^{-5}$	2.827	$1.7\ 10^{-5}$	0.071	0.98	**
Wild♀	TL	3.464	1.050	1.798	0.012	0.99	**
	CFL	-2.942	1.054	2.184	0.014	0.99	**
	LD1	5.339	0.263	1.072	0.007	0.97	**
	TW	$3.6\ 10^{-5}$	2.871	$2.2\ 10^{-5}$	0.114	0.97	**
Fattened	TL	4.244	1.051	0.846	0.004	0.99	**
	CFL	0.873	1.037	1.129	0.005	0.99	**
	LD1	7.102	0.257	0.603	0.003	0.95	**
	TW	$1.9\ 10^{-5}$	3.016	0.000	0.044	0.97	**

Table 3. Tests (t-Student) of isometric growth for wild and fattened bluefin tuna (p = 0.01).

	X=FL	*b*	*SEb*	*tobs*	*Allometry*
Wild	TL	1.051	0.008	6.664	+
	CFL	1.028	0.007	4.007	+
	LD1	0.252	0.005	158.980	-
	TW	2.790	0.047	4.465	-
Wild ♂	TL	1.071	0.014	5.177	+
	CFL	1.017	0.011	1.489	=
	LD1	0.251	0.006	114.994	-
	TW	2.827	0.071	2.452	-
Wild ♀	TL	1.050	0.012	4.279	+
	CFL	1.054	0.014	3.820	+
	LD1	0.263	0.007	106.112	-
	TW	2.871	0.114	1.126	=
Fattened	TL	1.051	0.004	12.720	+
	CFL	1.037	0.005	6.720	+
	LD1	0.257	0.003	259.434	-
	TW	3.016	0.044	0.351	=

Table 4. Tests (t-Student)of comparing of LLRs and LWRs between wild and fattened bluefin tuna (p =0.05).

X = FL	Intercepts a_1 and a_2				Slopes b_1 and b_2			
Y =	Wild	Fattened	t	a_1 anda_2	Wild	Fattened	t	b_1 and b_2
TL	3.850	4.244	1.682	=	1.051	1.051	0.003	=
CFL	0.596	0.873	4.657	≠	1.028	1.036	0.714	=
LD1	7.104	7.102	4.153	≠	0.252	0.257	0.786	=
TW	$5.2\ 10^{-5}$	$1.9\ 10^{-5}$	11.391	≠	2.790	3.016	4.712	≠
Y =	Wild ♂	Wild ♀			Wild ♂	Wild ♀		
TL	1.001	3.464	1.018	=	1.071	1.798	1.193	=
CFL	1.658	-2.942	1.164	=	1.012	2.184	2.002	=
LD1	6.892	5.339	0.860	=	0.251	1.072	1.325	=
TW	$4.4\ 10^{-5}$	$3.6\ 10^{-5}$	1.012	=	2.827	2.871	0.238	=

Table 5. Parameters of LWRs for wild and fattened bluefin tuna from Mediterranean Sea by different authors.

Authors		a	b	n	Area
ICCAT Manual 2010	Wild	$2.95\ 10^{-5}$	3.009	-	Mediterranean
El Tawil et al., 2004	Wild	$4\ 10^{-5}$	2.821	790	Libya
Aguado-Gimenez and García-García, 2005b)	Wild	0.070*	2.72	336	Balearic Waters
Hattour, 2003	Wild 2000	$4\ 10^{-5}$	2.429	390	Tunisia
	Wild 2001	$2\ 10^{-5}$	2.964	175	
Tzoumas et al., 2010	Wild	$5.94\ 10^{-5}$	2.752	416	Greece
Present work	Wild	$5.2\ 10^{-5}$	2.790	170	Tunisia
Sinovcic et al., 2004	Fattened+	$2\ 10^{-5}$	2.96	534	Adriatic Sea
Katavic et al., 2002	Fattened	0.0050*	3.29	36	Adriatic Sea
Aguado-Gimenez, and García-García (2005b)	Fattened	0.0074*	3.19	223	Balearic Waters
Percin and Akyol 2010	Fattened	0.0053*	3.19	702	Aegean Sea
Tzoumas et al., 2010	Fattened	$0.83\ 10^{-5}$	3.182	2661	Greece
Present work	Fattened	$1.9\ 10^{-5}$	3.016	473	Tunisia

* Standardized to cm/g (Froese, 2006), + TW = a TL^b.

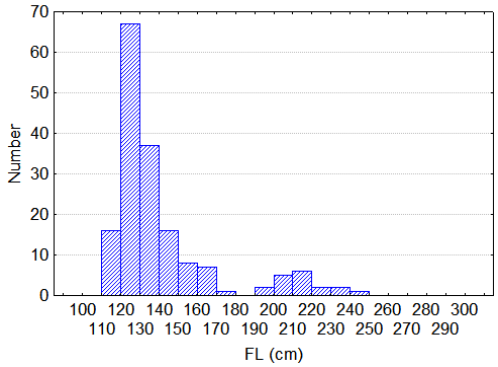

Figure 1. Fork length frequency distribution of wild bluefin tuna, caught in the Ionian Sea (Central Mediterranean).

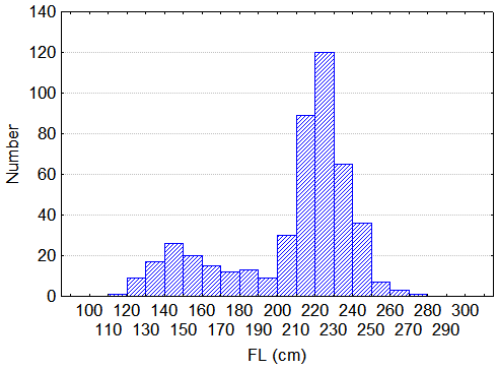

Figure 2. Fork length frequency distribution of fattened bluefin tuna, caught in the Ionian Sea (Central Mediterranean).

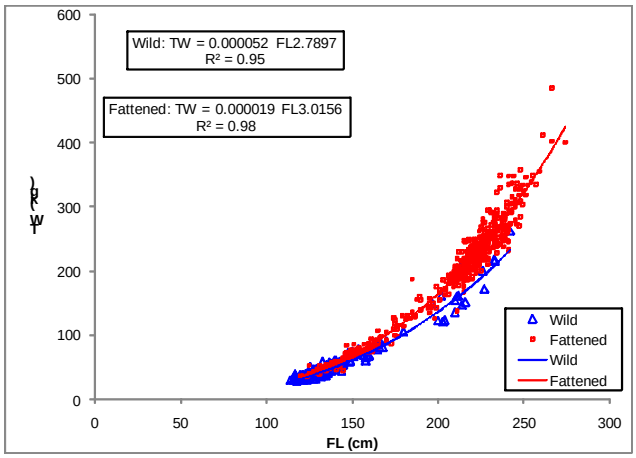

Figure 3. Relationships between fork length and total weight for wild and fattened bluefin tuna caught in the Ionian Sea (Central Mediterranean).

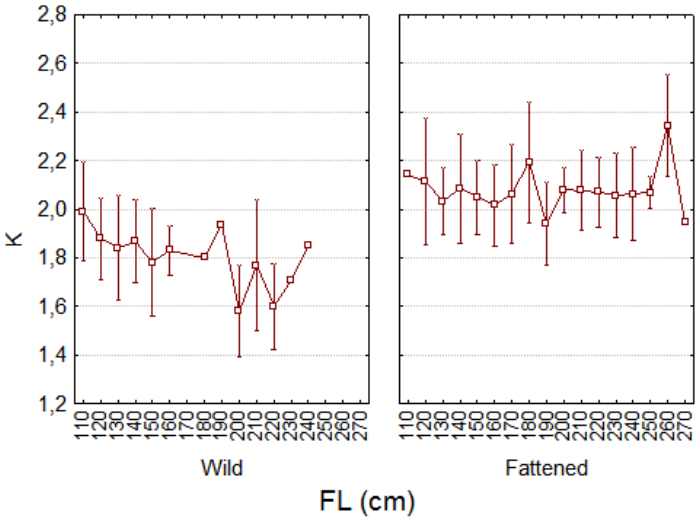

Figure 4. Mean condition factor (K) values (±SD) per length class (FL) for wild and fattened bluefin tuna caught in the Ionian Sea (Central Mediterranean).