BIOMETRIC RELATIONSHIPS AND FATTENING RATE OF BLUEFIN TUNA *THUNNUS THYNNUS THYNNUS L. 1758 IN* A TUNISIAN FISH FARM.

Abdallah HATTOUR[1] and A. MOUSSA[2]

1-Institut National des Sciences et Technologie de la Mer, 28, rue 2 mars 1934-2025- Salammbô- Tunisie.
abdallah.hattour@instm.rnrt.tn
2-Institut Supérieur de Biotechnologie de Monastir

ملخص

دراسة علاقات القياسات البيولوجية و نسبة تسمين سمك التن الأحمر بالأقفاص التونسية بدأ تصدير سمك التن الأحمر عبر إنتاج المضارب. وبعد انهيار هده التقنية الضاربة في القدم سنة 2003 أصبح صيد هده الأسماك حكرا على سفن الشباك الدائرة. يتم جلب المحصول ثم وضعه بالأقفاص و تعليفه لمدة تتراوح بين 4 و 6 أشهر قبل قتله و تصديره.
و حتى نساهم في القرارات التي تهدف حسن التصرف في استغلال الأسماك عملا على أخد المعلومات التي تهم معدل أحجام الأسماك عند اصطيادها ثم بعد فترة التسمين و تقييم نسبة التسمين و هو من الثوابت الأساسية عند تقييم مخزون سمك التن الأحمر.
أبرزت النتائج المتحصل عليها أن ليس لمعدل طول الأسماك قبل و بعد التسمين أي دلالة خلافا لمعدل الأوزان الذي تطور ب 55 بالمائة في مدة 4 أشهر من التسمين.
كلمات مفاتيح : تن أحمر- تسمين- توزيع الطول والوزن - أقفاص.

RESUME

Relations biométriques préliminaires et taux d'engraissement du thon rouge *Thunnus thynnus thynnus L.,* 1758 élevé dans une ferme tunisienne : Une analyse des données de thon rouge d'une ferme tunisienne durant les mois de juin à novembre 2008 est présentée. Les données disponibles sont réparties en deux séries, la première concerne des spécimens échantillonnés lors du remorquage des thons à la ferme et pendant la période d'acclimatation. La deuxième série groupe les spécimens échantillonnés à la fin de l'activité de l'engraissement. Le groupe sauvage est composé de spécimens dont la longueur à la fourche varie de 90 à 276 cm, alors que l'engraissé comprenait des spécimens dont les taille à la fourche varient de 105 à 310 cm. La proportion de juvéniles des spécimens engraissés (15.7%) est relativement faible comparée à celle des spécimens sauvages (61,8%). La répartition des masses totales des spécimens abattus montre une prévalence de la classe 31-50 kg soit (60,4 %). Les relations L-W, basées sur 1727 spécimens prélevés au cours de la période d'engraissement ont été déterminées pour chaque groupe. Des relations préliminaires taille-longueur de la tête et taille-hauteur maximale ont été estimées pour les spécimens engraissés. Ces relations reposent respectivement sur 1547 et 684 spécimens. Par ailleurs les masses totales des spécimens engraissés sont plus élevé que celles des spécimens sauvages pour une même taille. Enfin les spécimens de taille à la fourche entre 90 et 160 cm présentent un taux d'engraissement plus élevé (42 %) que ceux de taille supérieure à 160 cm (32 %).
Mots clés: Thon rouge, *Thunnus thynnus*, engraissement, distribution taille-masses,Tunisie.

ABSTRACT

An analysis of data from a Tunisian farm during the months of June to November of the year 2008 is presented. These data were broken down into two sets the first concern sampled fish while towing them to farm (wild set), the second set concern sampled specimen at the end of fattening process (fattening set).
The wild group comprised specimens ranging from 90 to 276 cm fork length, and the fattened group included specimens from 105 to 310 cm. Juvenile proportion (Lf<130 cm) in fattened specimen (15.7%) was considerably smaller compared to the proportion in wild specimens (61,8%). The distribution of individual weights of slaughtered BFT shows the prevalence 31-50 kg specimen class (60.4%). The L-W relationships were determined for each of these sets. This relationship was based on 1727 specimens sampled during the fattening period. A preliminary Fork length-Head size and Fork length Maximum height relationships were estimated for fattened specimens. Those relationships were based respectively on 1547and 684 specimens. The RWT of fattened specimens meant a higher weight than in wild BFT for the same size. Fish size between 90 and 160 cm Fl presented a higher fattening rate (42%) than larger fish (>160 cm Fl) (32%).
Key words: Bluefin tuna, *Thunnus* thynnus, fattening, length-weight distribution, Tunisia.

INTRODUCTION:

In Tunisia during the eight years (2003-2010) bluefin tuna farming production reached 2500 tons per year (Hattour, 2005a). The industry concerns 4 commercial companies located in the sites of Hergla (Sousse) and Chebba-Salakta (Mahdia) (fig.1). Since the total collapse of the traps, farming is based on fishing BFT by purse seine and growing them for a few months in cages of 50 m diameter located in about 35-40 m depth (Hattour, 2005b, c; Hattour, 2003),),.

The success of this activity is based on the specific characteristics of BFT. Indeed, BFT has particular adaptations which permit them to have a high metabolic rate (Dewar and Graham, 1994; Brill *et al*., 2001), additionally to their high rate of food assimilation and conversion, with the capacity to digest proteins three times faster than other fish (Graham, 1975; Stevens and McLeese, 1984). During breeding, adult BFT lose weight as they feed very little (Cort and Liorzou, 1991) or don't feed at all (Hattour, 2000). After spawning bluefin tuna feed actively to compensate weight's lost.

Despite the wide distribution of this activity around the Mediterranean basin and its high production, a lack of knowledge persists about biology and the effect of environmental conditions on the growth rate performance of these fish in cage.

Considering the change of morphometric relationship in fish due to physiological status (Weatherley and Gill, 1987) the general aim of this study was to follow the Recommendation of *International Commission for the Conservation of Atlantic Tunas (ICCAT)* on Bluefin Tuna Farming [Rec. 06-07] by studying some length weight relationships of BFT during fattening process in cages and estimate their growth rate at the end.

MATERIAL AND METHODS

Sampling.

Fish were caught by purse seine during May and June 2008 in the eastern Mediterranean Sea and towed to fattening cages. During acclimation period and before starting the feeding, dead specimen were sampled as wild ones.

Two datasets were analyzed: one resulted from the sampling specimen dead from natural causes during the transfer from the towing cage to the fattening cage, and during the acclimation period. The second set resulted from sampling specimen taken during slaughtering operations at the end of the fattening period, from June to November 2008.

In order to estimate the size and weight distribution of BFT, individual weights and fork length were taken from wild and fattened specimens.

For sampled specimen, the size of the head (HL), the maximum dorsal-ventral height (Mh), Fork length (FL) was measured to the near cm and the round weight **(**RW**)** to the nearest kg.

Measurements are defined below:

- Fork length (FL): is the straight line from the end of the upper jaw (end of the snout) to the posterior of the shortest caudal ray (fork of the caudal fin).
- Round weight (RW): is the weight of the whole specimen before any treatment or dressing.
- Head length (HL): is the straight distance from the tip of the upper jaw to the posterior end of the opercula.
- Maximum dorsal-ventral height (Mh): is the curved distance of maximum width of the specimen.

The Fulton's condition index was used to check fattened and wild specimen condition during the study period.

Given the impossibility of distinguishing the sex of the sampled specimen during their treatment by several Asian specialists, it was decided to omit this feature and all results were conducted as sex grouped.

Statistical analysis:

The Shapiro-Wilk.test is used to test the null hypothesis that the wild and fattened BFT came from a Normal distribution. The test rejects the hypothesis of normality when the p-value is less than or equal to 0.05.

The allometric equation was used to fit the length-weight relationship, $W= aL^b$, where W and L are variables, a and b are parameters. The coefficient of determination (r2) was used as index of the goodness of the estimates and standard error was calculated for parameters estimations.

A Boxplot was used as a convenient way of graphically depicting the 2 sets (weights and size) of the 4 groups of numerical data (Wild and fattened specimens 90-160 cm and >160cm FL) through the smallest observation (sample minimum), lower quartile (Q1), median (Q2), upper quartile (Q3), and largest observation (sample maximum). The aim of this Boxplot is to display differences between wild and fattened populations and to compare distributions between sets of wild and fattened specimen. The spacing between the different parts of the box indicates the degree of dispersion (spread) in the data. The top and bottom of the box are the 25th and 75th percentile (the lower and upper quartile, respectively), and the band near the middle of the box is the 50th percentile (median).

A median test (Mood test) was performed to test the null hypothesis that two samples came from a population having the same median.

For comparison of length-weight relationships of fattened and wild specimen, the analysis of covariance (ANCOVA) was used. We tested the fattening activities effect on the outcome variable,

after removing the variance for which quantitative predictors (covariance) account.
The F-test assumes that the errors are normally distributed and homoscedastic. Since ANCOVA is a method based on linear regression, the relationship of the dependent variable (FL) to the independent variable (RW) is linear in the parameters.
In this case, considering the individual variability of the total masses of fattened specimen, we did use the Fulton's condition factor (K). This index is indicating the physiological state of specimen and is defined by the relationship between the weight and size of specimen with the intention of describing the "condition" of individuals. It is given by the formula (Tesch, 1968; Santic *et al.*, 2006; Olim and Borges, 2006):

$$K = (RW / FL^b),$$

Where RW = total weight of specimen in kg; FL = Fork length of specimen in cm; b= allometric coefficient, is the exponent of the weight-length $RW = aFL^b$ relationship.
In the calculations, we used the coefficient b of the general equation with two values corresponding to the wild and the fattened specimen. Fulton's body condition factor (*K*) was estimated for each individual.
Successive tests are used on numerical facts (k) to compare entities estimated on wild and fattened BFT.
1-Tests of Homogeneity of Variances (new.sta)
2-Test Kruskal Wallis or « analysis of variance by ranks » (ANOVA Nonparametric, Population variances were heterogeneous).

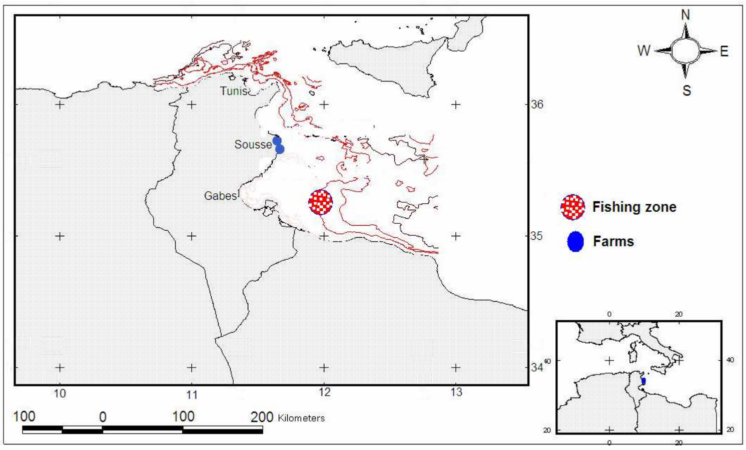


Figure1. Fishing area and geographical location of Tunisian farms.

RESULTS

Normality test: Shapiro-Wilk

Table I: Summary statistics

Variable	Observations	Minimum	Maximum	Mean	Std.Deviation
Fattened W	1510	9.000	288.000	46.421	53.329
Fattened Fl	1510	94.000	291.000	138.830	38.416
Wild W	217	7.000	206.000	42.571	48.447
Wild Fl	217	90.000	276.000	144.696	45.937

Table II: Shapiro-Wilk test (Fattened and Wild bluefin tuna)

	Fattened W	**Fattened Fl**	**Wild W**	**Wild FL**
W	0.602	0.719	0.665	0.764
p-value	< 0.0001	< 0.0001	< 0.0001	< 0.0001
alpha	0.05	0.05	0.05	0.05
Test interpretation	As the computed p-value, in each samples is lower than the significance level alpha=0.05, we conclude that all variables from which the sample was extracted do not follow a Normal distribution. . The risk to reject the null hypothesis H0 while it is true is lower than 0.01%.			

Non parametric test: Kolmogrov-smirnov test: Fattened and wild Weight and Fork length

Hypothesized difference (D):0
Significance level (%):5

Table III: Kolmogrov-smirnov test Fl and RW of fattened and wild BFT

	Fattened and wild Weight	**Fattened and wild Fork Length**
D	0.290	0.087
p-value	< 0.0001	0.070
alpha	0.05	0.05
Test interpretations	p-value is lower than the significance level alpha=0.05, the distributions of the two samples are different The risk to reject the null hypothesis H0 while it is true is lower than 0.01%	p-value is greater than the significance level alpha=0.05, the distribution of the two samples follow the same distribution. The risk to reject the null hypothesis H0 while it is true is 7.04%.

The Test of Mann-Whitney gives identical conclusion.

ANCOVA test: length-weight regression of fattened and wild specimen

For the comparison of the length-weight regression of fattened and wild specimen the ANCOVA test was performed. It indicated that the two regressions were not significantly different.

Table IV. Results of ANCOVA test, comparing length-weight regressions of fattened and wild specimen

Regression	**Sum x2**	**Sum xy**	**Sum y2**	**SCE res.**	**ki**
Reg. Wild BFT	16.627	52.047	167.260	4.332986	1
Reg. Fattened BFT	81.573	258.587	875.876	56.151160	1
k et Som ni					**2**
Grouped Regression				60.484	
Common Regression	98.200	310.635	1043.136	60.506	
F =	0.62				
$F_{(0,05(1); 2; 1724)}$ =	3.00				
	Regressions are not significantly different				

The substantial individual variability of the gain weight during the fattening period has probably hidden the differences of the regressions of the two groups.

Comparison of Fullton's condition factor (K).

The test of homogeneity of Fulton's condition factor (K) of the two groups of fish (wild and fattened) revealed that the variances were not homogeneous (Table. V) that is why we were not allowed to perform a parametric ANOVA. Thus, the Kruskal Wallis Test (nonparametric ANOVA for nonhomogeneous variances data), was used to test the hypothesis of similarity of Fullton's condition factors (K) of the two groups of BFT. The hypothesis of similarity was rejected (Chi-Square = 192, 0220, df = 1, p = 0.000) (Table VI).

Table V. Result of the tests of Homogeneity of Variances.

	Hartley	Cochran	Bartlett		
	F-max	C	Chi-sqr	df	p
VAR2	3,51274586	0,77840543	109,337685	1	1,50487E-25

Table VI. Descriptive statistic parameters of the two groups

Descriptive statistics	***K - Wild***	***K - Fattened***
Mean	10,1521028	13,3027629
Standard error	0,09866528	0,06971358
Median	10,2102944	12,7314815
Mode	8,26446281	11,5740741

Standard deviation	1,45343026	2,70898039
Variance	2,11245953	7,33857477
Coefficient d'asymétries	0,08913692	0,81840679
Range	7,75480451	15,2476536
Minimum	6,24370556	8,04310519
Maximum	13,9985101	23,2907588
Sum	2203,0063	20087,1719
N	217	1510
Confidence Interval (95,0%)	0,19446999	0,13674579

Fullton's condition factor (K) of the two groups is significantly different.

Size composition:
The size distribution of BFT showed two similar aggregated groups for wild and fattened specimen. The fork length of the first group ranged between 90 and 160 cm, while that of the second group was ranged between 210 and 250 cm (Fig. 2).

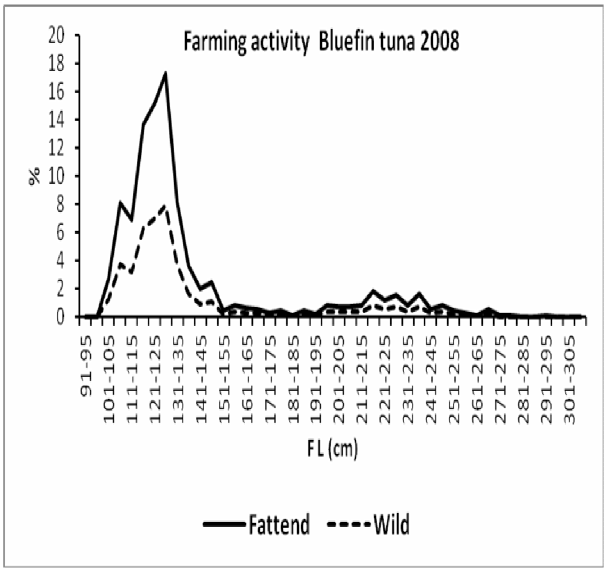


Figure 2. Fork length percentage distribution of bluefin tuna (wild and fattened) caged in a Tunisian farm from June to November 2008

The wild group comprised specimens ranging in fork length from 91 to 276 cm, and the fattened group included specimens from 105 to 310 cm (fig.3). The proportion of large tuna (FL> 250cm) was 1.2% for wild specimens and 4,8% for fattened group.
Based on ICCAT limit size reference for breeding (130 cm), the proportion of spawning tuna caged in 2008 reached respectively 38.2% and 84.3% for wild and fattened specimen.

Weight composition:
The distribution of individual weights of slaughtered BFT after six months of fattening shows the prevalence of 31-50 kg specimen class which represented 60.4%. The 51-75 kg specimen represented 17.5%, while those larger than 200 kg, represented 11.4% of slaughtered specimen (fig.5).

Biometric relationships: Since length and weight variable from which the sample was extracted does not follows a normal distribution, all calculation of biometric relations was based on non parametric regression.

Relationships between fork length and round weight: Functions and parameters are shown in Figures 5 A, B and C. The corresponding data are indicated in the table VII.

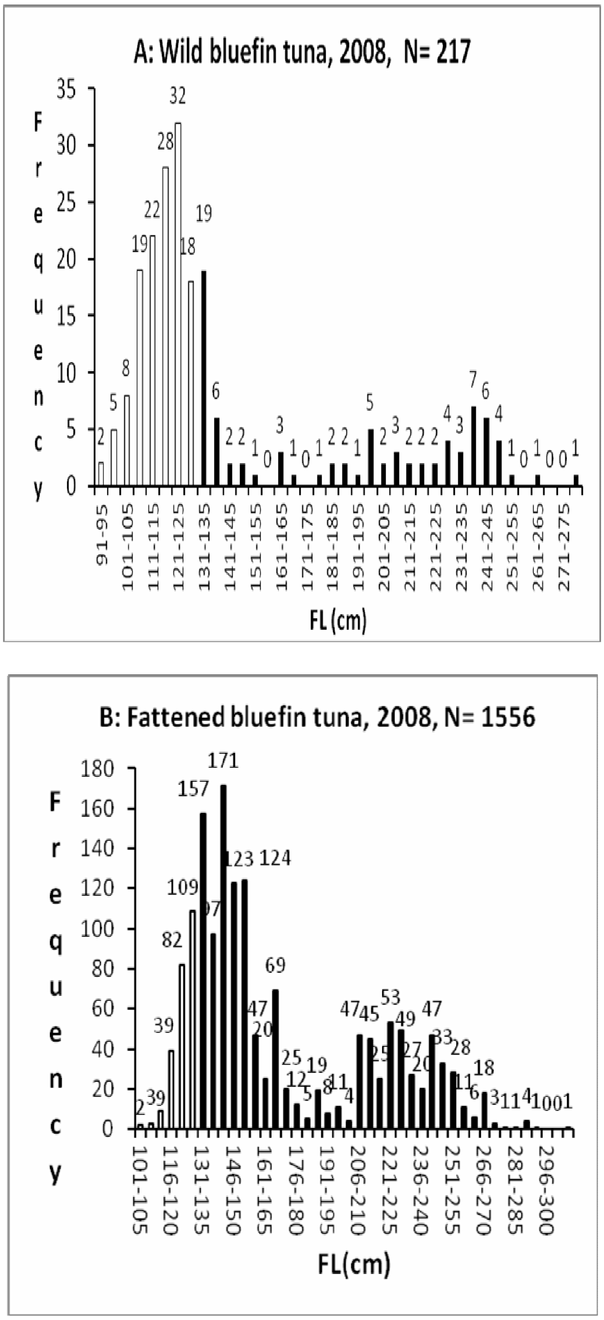


Figure 3 A, B. Fork length (FL) frequency distribution of BFT caged since June to November 2008.

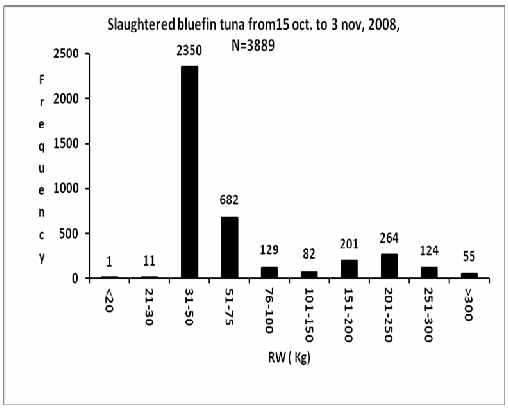
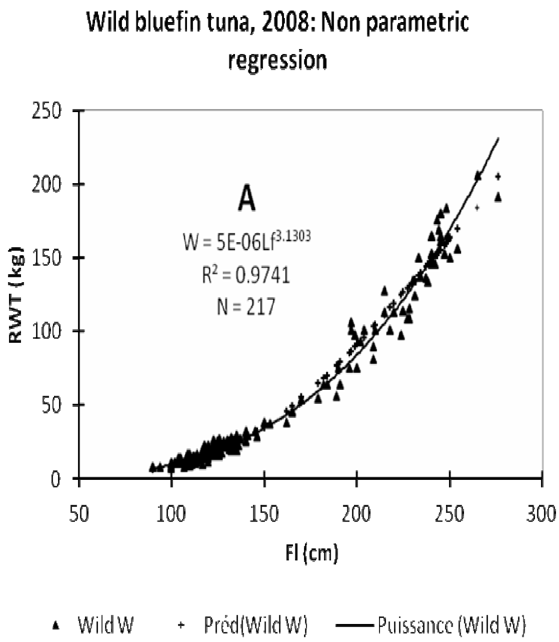
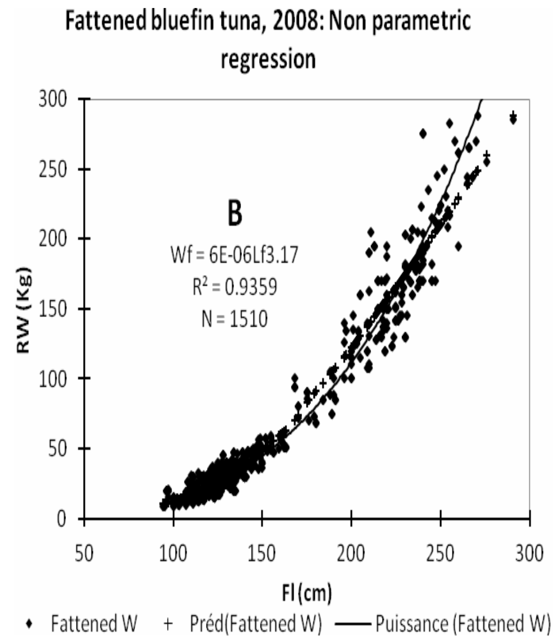


Figure 4. Weight distribution of bluefin tuna caged since June to November 2008.





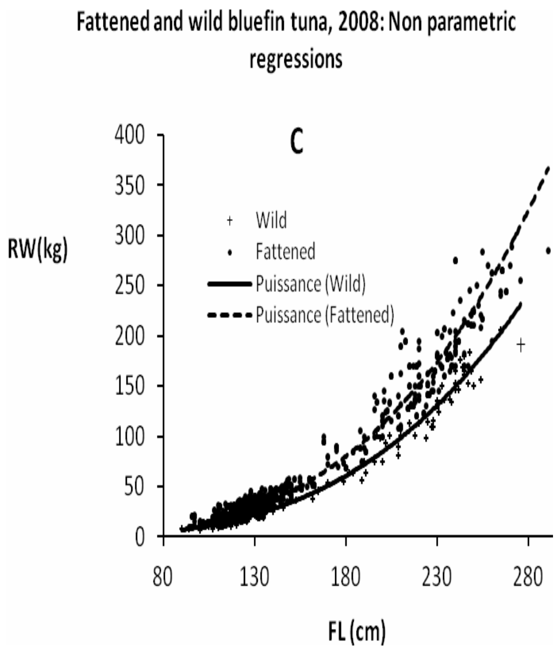


Figure 5 A, B et C. The relationship between fork length and round weight of wild and fattened bluefin tuna (mixed)

Table VII. Relationships fork length (FL) and round weight (RW) of wild and fattened bluefin tuna, "a" and **"b"** constants of the equations RW= a * FL^b, **N =** number of pairs of values, **R=** correlation coefficient.

	Groups Length (cm)	a	b	R	N	Intervals FL (cm)	Intervals RW (Kg)
Wild BFT	90≤FL≤160	$2*10^{-6}$	3.3316	0.8999	164	90≤FL≤153	7<RW≤38
	FL>160	$6*10^{-6}$	3.1152	0.9449	53	162≤FL≤265	38<RW≤206
	FL>90	$5*10^{-6}$	3.1303	0.9870	217	90≤FL≤265	7≤RW≤206
Fattened BFT	105≤FL≤160	$2*10^{-6}$	3.4242	0.8501	1269	94≤FL≤160	9≤RW≤59
	FL>160	$3*10^{-5}$	2.8595	0.9227	241	161≤FL≤291	51≤RW≤288
	FL>90	$6*10^{-6}$	3.1700	0.9674	1510	94≤FL≤291	9≤RW≤288

Relationship between Fork length and head size: The relationship between fork length (FL) and head size (HL) are shown in **Figure 6**.

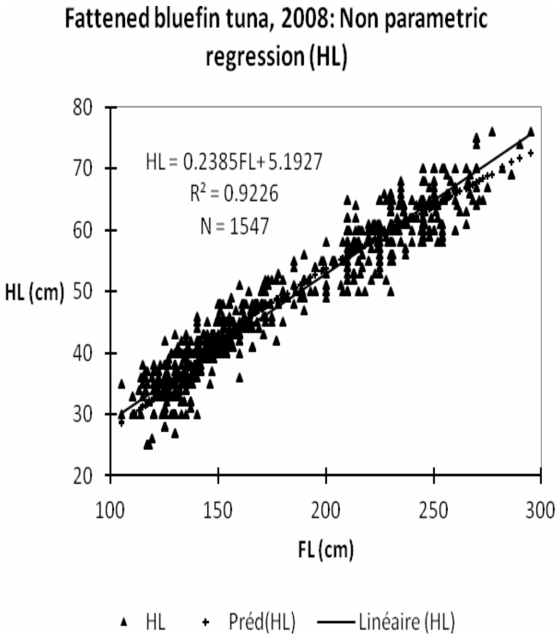


Figure 6. The relationship between fork length (FL) and head size (HL) of fattened bluefin tuna .

Relationship between Fork length and Maximum height: The relationship between Fork length (FL) and the maximum height (Mh) are shown in **Figure 7**.

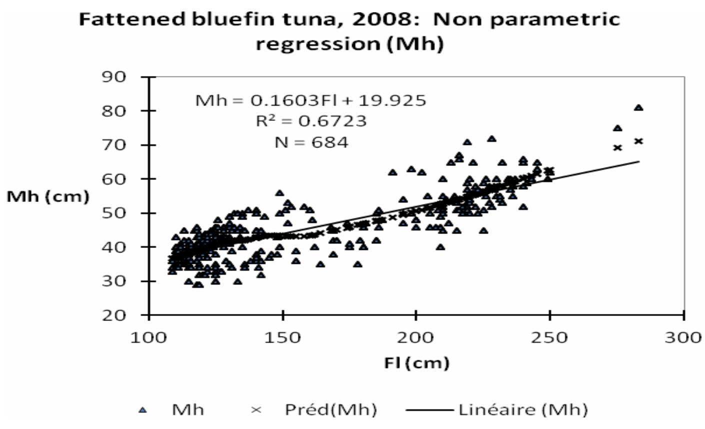


Figure 7. The relationship between fork length and maximum dorsal-ventral height (Mh) of fattened bluefin tuna (mixed). Means and Standard deviation are indicated in Table IX.

Boxplots analysis

Box plot of fork length (**Fig. 8)** in wild and fattened specimen showed that the median and corresponding distribution were similar. The distribution in the group 90-160 cm displayed a peak around the median, which box, containing 50% of data, ranged approximately from 110 to 124 FL in wild tuna and from 115 to 130cm for fattening specimen. For the second group (> 160cm) the distribution displayed a peak around the median, which box, containing 50% of data, ranged approximately from 198 to 240 cm FL in wild specimen and from 202 to 240 cm for fattened specimen.

The Mood test showed that fork length of wild and fattened BFT came from a population having the same median, the computed p-value is greater than the significance level alpha=0.05 (Table VIII). This confirms the approach of the SCRS assuming that there is no increase in length in BFT held in farms for a short period, even if the research carried out by Aguado-Gimenez & Garcia-Garcia (2005a, b) and Gimenez-Casalduero & Sanchez-Jerez (2006) has shown a clear increase in length.

Table VIII: Mood test for 5% as significance level

	Lf<160 cm	**Lf>160 cm**
U	0.260	0.260
Critical value	3.841	3.841
DF	1.000	1.000
p-value	0.610	0.610
alpha	0.05	0.05
Test interpretations	Medians of wild and fattened FL are equal	

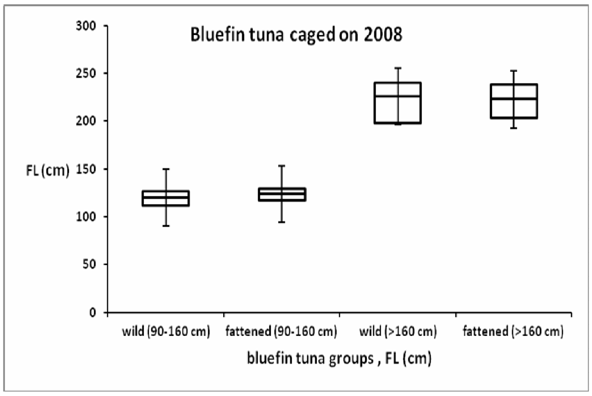


Figure 8. Boxplot of wild and sacrificed BFT length in 2008. The box represents all cases, and extends from 25th to the 75th quartiles. The line inside the box shows the median.

Boxplots of tuna specimen weight (**Fig. 9**) in wild and fattened specimen shows that the median and corresponding distributions were different inside each group. The distribution in the group 90-160 cm displayed a peak around the median, which box, containing 50% of data, ranged approximately from 15 to 25 kg in wild tuna and from 20 to 30 kg for fattened specimen. For the second group (> 160cm) the distribution displayed a peak around the median, which box, containing 50% of data, varied approximately from 90 to 153 kg in wild tuna and from 120 to 190 kg for fattened specimen. The spread of the distribution was much lower in the first group comparatively to the group of specimen with size larger than 160 cm FL.

The Mood test showed that weight of wild and fattened BFT came from a population having different median (the computed p-value is lower than the significance level alpha=0.05) (Table IX). This difference is explained by the increased over time of the fattened specimen weight.

Table IX: Mood test for 5% as significance level

	Weight for Lf<160 cm	**Weight for Lf>160 cm**
U	9.672	9.672
Critical value	3.841	3.841
DF	1.000	1.000
p-value	0.002	0.002
alpha	0.05	0.05
Test interpretations	Medians of wild and fattened weight are not equal	

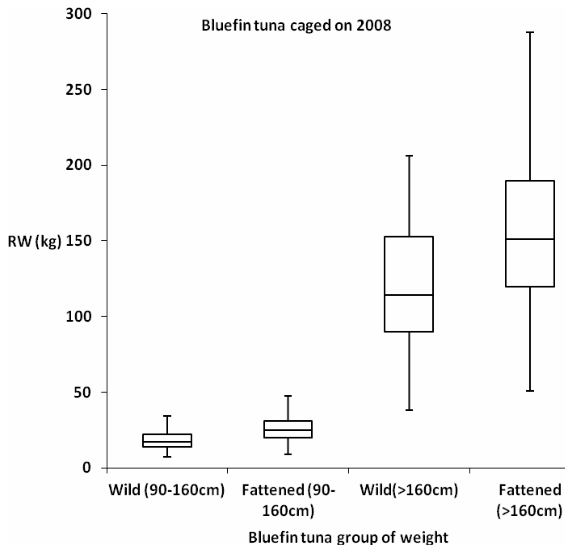


Figure 9. Boxplot of wild and sacrificed BFT weight in 2008. The box represents all cases, and extends from 25th to the 75th quartiles. The line inside the box shows the median.

Weight Increase

After six months of fattening, a significant increase of weight was observed in BFT from 29 to 55% for the first group (90<FL<160) and from 34 to 40% for the second group (FL>160 cm)

DISCUSSION

Basically, we believe that growth rate is highly variable depending on various factors, such as season, year, duration of caging, initial size of the specimen, feeding, location, environmental conditions, etc. The significant augmentation of weight observed in BFT (from 29 to 55%, Table VII) during six months of fattening is in agreement with their high rate of food conversion (Graham, 1975). Much of fattened fishes prior their settlement in cages was in reproductive stage. As they do not feed during the reproduction migration (Rodriguez-Roda, 1964, Hattour, 2000), they use all the fat reserves they previously accumulated to produce mature eggs. In fact, level of lipid content measured by Establier (1963) from BFT during spawning period caught by traps was 1.33±0.36%, whereas tunas collected during outmigration from the Mediterranean Sea had a 25.20±2.00% of lipid contents (Establier, 1963). These results are also confirmed by Gimenez-Casalduero and Sanchez-Jerez (2006) on fattening tuna in two Spanish farms, where rates of lipid content evolve from 1.6±0.9% and 2.5±0.9% in June to 22.4±1.7% and 15.6±1.2% in November. Furthermore, data of June correspond to the fish caught during the spawning period, when the specimen had active gonad development (Corriero *et al.*, 2003).

According to theoretical length weight equations for the two groups, the fattening process meant a higher weight in fattened than in wild BFT for the same size. This difference is more pronounced for greater fork length (Fig. 6). The growth rate varied then from 51.7 to 60% (mean: 57.5) for the smallest size (<160 cm) and from 32.6 to 50.9 (mean: 49.6) for specimens more than 160 cm LF. As environmental conditions are similar (Block *et al.*, 1997) with sufficient food for all occupants of cages (food almost permanently available, specimen fed to satiety), this difference can be explained by the fact that specimen of smaller sizes (90 to 160 cm FL) have higher growth and feed conversions rate than larger specimen (>160 cm LF). This difference was also observed by Katavic *et al.*, (2002), who found that the difference between fattened and wild BFT appeared only above 110cm FL.

Tičina *et al.*, (2006) reported significantly higher growth rates for small (juvenile) BFT in cages. These authors also indicated that small BFT are able to increase their initial biomass by more than 340% within 511 days (Tičina *et al.*, 2007). After an extended fattening period (>1 year) one year old tuna increased considerably their biomass, i.e juvenile BFT gained weight twice as fast in cages compared to the wild.

Aguado-Giménez and Garcia-Garcia, 2005b, noticed that differences in weight and somatic conditions of wild and fattened BFT were not so clear below

180cm FL. For these authors, as small tuna are in growth phase; their high metabolic rate would not permit them to become overweight.

Wild BFT confined in cages and fed to satiety with high lipid content specimen were able to recover initial weight (before reproduction) and exceed it within a short period. Indeed, less energy is spent for searching prey with favorable conditions. Nevertheless, increasing weight was not accompanied by appropriate length increase (Aguado-Gimenez and Garcia-Garcia, 2005b).

Our results were in agreement with those collected by Lovatelli, (2005) concerning fattening rate of BFT. This rate, which relayed on estimation of the specimen biomass stocked in cages at the beginning of the process, could be considered highly biased because this initial biomass can't be strictly quantified.

After six months of fattening, gain is 20 to 50% in Italy and 25 to 40% in Malta; it is 40 to 50% in Spain for individuals of 50 to 100 kg and 10 to 30% for individuals of 100 to 150 kg. In Turkey this gain is 50 to 60% (25 to 100 kg) and in Cyprus it is between 10 and 23%. Nevertheless the SCRS Committee (ICCAT, 2009) assumed that large specimen held for several months of fattening, gain on average 25% of their capture weight (i.e. a conversion factor of 0.8).

CONCLUSION

The sizes of wild and fattened BFT were ranging from 91 cm to 310 cm FL, with peaks at the size classes of 130 cm and 220-240 cm FL. No differences were observed in length structure of wild and fattened group. The proportion of spawning tuna caged in 2008 reached respectively 38.2% and 84.3% for wild and fattened specimen.

The linear regression analysis results show a strong correlation between the round weight and the fork length for wild and fattened specimen and also for head length (HL), maximum dorsal ventral height (Mh) and the fork straight length (FL).

Boxplot of specimen size showed that the medians were similar in both groups, but differences existed in weight distribution. This study concerning BFT fattening in Tunisia, demonstrated the biomass increase achieved by the farming of BFT in growth-out floating cages. The growth rate obtained (29 to 55%) is specific to Tunisian farms; it provides important information on the growth performances of Tunisian BFT under specific rearing conditions

Acknowledgement: We would like to thank all members of the Farm Administration team for providing facilities during the realization of this study, particularly for their meaningful help during the sampled time.

BIBLIOGRAPHY

1

Aguado-Gimenez, F. & Garcia-Garcia, B., 2005a. Growth, food intake and feed conversion rates in captive Atlantic bluefin tuna (*Thunnus thynnus* Linnaeus, 1758) under fattening conditions. Aquacult. Res., 36: 610-614.

Aguado-Gimenez, F. & Garcia-Garcia, B., 2005b. Changes in some morphometric relationships in Atlantic bluefin tuna (*Thunnus thynnus thynnus* Linnaeus, 1758) as a result of fattening process. Aquaculture 249 (2005) 303-309.

Block, B. A.., Keen, J. E., Castillo, B., Dewar, AR. H., Freund, E. V., Marcinek, D. J., Brill, R. W. & Farwell, C., 1997. Environmental preferences of yellowfin tuna (*Thunnus albacores*) at the northern extent of its range. Marr. Biol., 130:119-132.

Brill, R., Swimmer, Y., Taxboel, C., Cousins, K. & Lowe, T., 2001. Gill and intestinal Na+ - K+ATPase activity, and estimated maximal osmoregulatory costs, in three high-energy demand teleosts: Yellowfin tuna (*Thunnus albacares*), skipjack tuna (*Katsuwonus pelamis*), and dolphin fish (*Coryphaena hippurus*). Mar. Biol., 138: 935-944.

Corriero, A., Desantis, S., Deflorio, M., Acone, F., Bridges, C. R., De La Serna P., Megalofonou, P. & De Metrio, G., 2003. Histological investigation on the ovarian cycle of the BFT in the western and central Mediterranean. J. Fish Biol., 63(1): 108-119.

Cort, J.L.. & Liorzou, B., 1991. Migration eastern Atlantic and Mediterranean. In Deriso, RB, Bayliff, W.H. (Eds), World Meeting on Stock Assessment of BFTs: Strengths and Weakness. Special Report-Inter-American Tropical Tuna Commission, vol.7, pp. 130-132.

Dewar, H. & Graham, J.B., 1994. Studies of tropical tuna swimming performances in a large water tunnelI. Energetics. J. Exp Biol., 192: 13-31.

Establier, R., 1963. Variación de la composición química del atún de Barbate (costa sudatlántica española) en relación a las distintas fases migratorias. Inv. Pesq., 22: 157-169.

Gimenez-Casalduero, F. & Sanchez-Jerez, P., 2006. Fattening rate of BFT *Thunnus thynnus* in two Mediterranean fish farms. Cybium, 30 (1): 51-56.

Graham, J.B., 1975. Heat exchange in the yellowfin tuna. *Thunnus albacores* and skipjack tuna *Katsuwonus pelamis* and the adaptative significance of elevated body temperatures in scombrid fishes. Fish. Bull., 73: 219-229.

Hattour, A., 2000. Contribution to the pelagic fish study in Tunisian waters. PhD. Thesis. University El Manar Tunis, Tunisia,. *327 p.*

Hattour, A., 2003. The Purse seine fishing of bluefin tuna (*Thunnus thynnus*) in the purse seine in Tunisia in 2001.. ICCAT-SCRS-02/050. Col. Vol. Sci. Pap. 55(1) .2003. pp204-216

Hattour, A., 2005a. The bluefin fattening activity in Tunisian waters. Col. Vol. Sci. Pap. ICCAT, 58(2) :606-614 (SCRS/2004/084)

Hattour, A., 2005b. Comments on BFT catches by Sidi Daoud tuna trap net . SCRS/2004/086 Col. Vol. Sci. Pap. ICCAT, 58(2): 622-629(2005)

Hattour, A., 2005c. An ancestral fishing technique: Preservation of the specificity of Tunisian trap net of Sidi Daoud , bluefin tuna (*Thunnus thynnu*s, Linnaeus, 1758) landing. Bull. Inst. Natn. Scien. Techn. Mer de Salammbô, Vol.32.

Iccat, 2009. International Commission for the Conservation of Atlantic Tunas -Report for biennial period, 2008-09 PART I (2008) - Vol. 2 English version SCRS, 271 p

Katavic, L., Ticina, V. & Franicevic, V., 2002. A preliminary study on the growth rate of bluefin tuna from Adriatic when reared in floating cages. Col.Vol.Sci.Pap ICCAT 54, 472-476.

Lovatelli, A., 2005. Summary report on the states of BFT aquaculture in the Mediterranean. *In Report of the third meeting of the Ad Hoc GFCM/ICCAT Working Group on sustainable bluefin tuna Farming/Fattening Practices in the Mediterranean. Rome, 16-18 March 2005. FAO Fisheries Report. N°779. Rome, General Fisheries Commission for the Mediterranean (GFCM).* International Commission of the Conservation of Atlantic bluefinTtuna (ICCAT), FAO. 2005.108p.

Olim, S., Borges, T.C., 2006. Weight–length relationships for eight species of the family Triglidae discarded on the south coast of Portugal. J. Appl. Ichthyol. 22, 257–259.

Rodriguez-Roda, J., 1964. Biología del atún, *Thunnus thynnus* (L.), de la costa sudatlántica d'España. Inv. Pesq., 25: 33-146.

Santic, M., Pallaoro, A. Jardas, I., 2006. Co-variation of gonadosomatic index and parameters of length–weight relationships of Mediterranean horse mackerel, Trachurus mediterraneus (Steindachner, 1868), in the eastern Adriatic Sea. J. Appl. Icthyol. 22, 214–217.

Stevens, E.D., & Mcleese, J.M., 1984. Why BFT have warm tummies: Temperature effect on trypsin and chymotrypsin. Am. Physiol. Soc., 246: 487-494.

Tesch, F.W., 1968. Age and growth. In: Methods for assessment of fish production in fresh waters. W. E. Ricker (Ed.). Blackwell Scientific Publications, Oxford, pp. 93–123.

Tičina, V., Grubisic, L. Katavic, I. Francievic, V. & Tičina, V.E., 2006. Report on research activities on BFT tagging within growth-out farming cages. Collect. Vol. Sci. Pap. ICCAT, 59(3): 877-881.

Tičina, V., Katavić, I. & Grubišić, L., 2007. Growth indices of small northern bluefin tuna (*Thunns thynnus*, L.) in growth-out rearing cages. Aquaculture 269 (2007) 538-543.

Weatherley, A.H. & Gill, H.S., 1987. The biology of Fish Growth. Academic Press, London. 443 pp.