Mediterranean Marine Science

Vol 15, No 1 (2014)

Vol. 15, No 1 (unpublished)

Temporal distribution of size and weight of fattened Bluefin tuna (Thunnus thynnus l.) from Tunisian farms: (2005-2010)

A. HATTOUR, W. KOCHED

doi: [10.12681/mms.513](https://doi.org/10.12681/mms.513)

Research Article

Mediterranean Marine Science
Indexed in WoS (Web of Science, ISI Thomson) and SCOPUS
The journal is available on line at http://www.medit-mar-sc.net
DOI: http://dx.doi.org/10.12681/mms.513

Temporal distribution of size and weight of fattened bluefin tuna (*Thunnus thynnus* L.) from Tunisian farms (2005-2010)

A. HATTOUR[1] and W. KOUCHED[2]

[1] Institut National des Sciences et Technologies de la Mer (INSTM)
28, rue 2 mars 1934 -2025- Salammbô
[2] Institut Supérieur de Biotechnologie de Monastir

Corresponding author: abdallah.hattour@instm.rnrt.tn

Handling Editor: Argyro Zenetos

Received: 25 June 2013; Accepted: 24 October 2013; Published on line: 5 December 2013

Abstract

The present study analyzed the size and weight frequency composition of Atlantic BFT *(Thunnus thynnus)* fattened in the Tunisian farms from 2005 to 2010 and compared these morphometric parameters with those of the wild ABFT landed on 2001 at Sfax port (Tunisia). A total of 6,757 wild and fattened ABFT were measured in terms of straight-line fork length and 49,962 were weighed. The mean value of Fulton's Condition Factor (K) for wild ABFT was 1.59, while the value of K from 2005 to 2010 was 2.43, 2.32, 2.15, 1.61, 1.79 and 1.90, respectively, for fattened ABFT after 5-6 months of fattening. The length frequency of fattened ABFT clearly showed a substantial increase in juvenile rate (under size of the first sexual maturity) and who have not yet reached 4 years of age. The percentage increase in the size and weight increased from 21.4% in 2005 to 31.3% in 2009. For weight distribution, 73.3% of the fish caught in 2001 were under the annual mean weight (75.7 kg), which means 71%-72% of the fattened fish were under the annual mean weight. In 2009, only 57% of the fattened fish were the under mean weight. This indicated that the fish being caught were becoming increasingly small. The mean weight during the fattening process (77-124 kg) was obviously higher than that of the wild fish (75.7 kg). This study showed an increase in the number of specimens under first sexual maturity, which did not spawn. This indicates over-exploitation; the implementation of recent regulations through the International Commission of Conservation of Atlantic Tuna ICCAT recommendations will reduce fish mortality rates and thus contribute to preserve this endangered species.

Keywords: Bluefin tuna, *Thunnus thynnus*, fattening, length distribution, weight distribution, farms.

Introduction

Atlantic bluefin tuna (ABFT) is a highly migratory tuna species and the largest migratory species in terms of size. In Tunisia, tuna were mainly caught using traps before the introduction of seiners (since 1978) for canning and were poorly marketed. This was partially because the catching period coincided with the spawning period characterized by fish with low lipid levels in the muscles and, to a minor extent, with the catches of juvenile fish. Both these fish products do not qualify for the lucrative sashimi market (Medina *et al.,* 2002; Corriero *et al.,* 2003). Since 2003, there has been an overall shift in targeting towards large bluefin tuna (ABFT) in the Tunisian waters in the Mediterranean Sea. As the majority of these fish are subjected to fattening process, it is crucial to obtain precise information regarding the total catch, actual size of the samples at the time of catch, size composition and individual weight after the fattening process. In Tunisia, the development of tuna farming since 2003 allowed these fish to be reared and fattened until their weight and flesh quality could meet the sashimi market standard. Generally, the period of tuna farming does not exceed 6 months. Tuna farming is based on massive capture of ABFT in the spawning area by using purse seine (Hattour, 2003) since the collapse of the traps (Hattour, 2005a, 2005b, 2005c) and farming them in 50 m diameter cages. The fish were fed a daily diet of high lipid content pelagic fish and a small amount of squid a few days before slaughtering (Hattour, 2009).

The global annual farmed ABFT harvesting has been continuously decreasing. Indeed, since the implementation of ICCAT's recommendations on the limitation of catches in the eastern Atlantic and Mediterranean (Rec. 08-04; 08-05; 09-06) and ICCAT's resolution to establish a multi-annual recovery plan, Tunisia was facing quota restrictions that brought down the national landing from 3249 tons in 2005 to just 1932 tons in 2009 (ICCAT, 2012).

Trends in weight and length composition data are useful as indicators of stock status and as inputs for stock assessments (SCRS, 2010). The present study describes the weight, size distribution and Fulton's Condition Factor of fattened ABFT based on the measurements performed over the 6-year period (2005-2010) in a Tunisian farm. These parameters were compared with those sampled from the wild ABFT landed in 2001 at Sfax port.

Materials and Methods

Sample collection

ABFTs were caught using a commercial purse seining during the fishing season and tracked to a fattening cage kept in water at a water depth of 35-40 m, off the central east coast of Tunisia. During the tracking and acclimatisation period, before beginning feeding and at the end of the fattening process, dead and slaughtered fish were sampled. For each sample, straight fork length (SFL) was measured and curved fork length (CFL) was measured to the nearest centimetre. Measurements were made from the tip of the upper jaw to the fork of the tail. For round weight (RW), the whole fish was weighed before any treatment or dressing. In most cases, the young fishes were weighed together in small groups by the fishmongers and the large fishes were individually weighed, both to the nearest kilogram. In total, 56,719 fish were randomly sampled on board by suppliers of fattening farms for fattening (2005-2010) and at Sfax landing port for wild fish (2001). Of these, 49,962 fish were sampled for weight distribution, while 6,757 fish were sampled for size distribution.

Considering the difficulty to obtain length and weight of the same fish sampled during their treatment by several quick and skilled specialists, we decided to separately treat the weighed and measured sample in farms from where the data were annually collected. Nevertheless, this task could be performed mainly for fish that died from natural causes while being transferred from the towing cage to the fattening cage during the acclimatisation period and the fattening process. At the end of the fattening process, the length of 5,307 fish and their weight were simultaneously measured. Records of fish with abnormal length/weight ratio, due to possible errors during data entry, were eliminated from the analysis.

Data analysis

Selection of the type of fork length: The selection of SFL based on the results of sampling investigations performed by observers is debateable.To avoid overestimation of weight from the sampled fish, we opted to measure SFL. In addition, our result is consistent with similar studies conducted by Salz *et al.* (2007).

Based on the length and weight data, we calculated the mean sizes and annual mean weight for each sample. Individuals were ranked as sub-adults and adults using 130 cm SFL as 100% maturity length (Hattour & Macias, 2002; Corriero *et al.,* 2005) for both the sexes. We analyzed the proportion of sub-adults and adults by campaigning for the study period.

Three datasets were analyzed: the first dataset resulted from the sampling of RW or SFL of wild fish landed on Sfax in 2001. The second dataset resulted from the sampling of RW or SFL of fish collected during slaughtering operations at the end of the fattening process, from June to November-December during 2005-2010. For the third dataset, SFL and RW were made simultaneously on the same fish.

Special care was taken during 2008 when the fishes were sampled under different ecological situations. In 2008, the fishes were sampled from towing, acclimatisation and fattening processes, including those that died naturally during fattening.

When the size and weight of ABFT were simultaneously measured, the Fulton's Condition Factor (K) for each fish and its mean K for the sample for each year were calculated. Measures of fish condition are considered to be reliable indicators of the energy reserves of fish. K values vary over the year because of spawning activities, with the lowest K value found during the spawning season.

K was calculated from the expression (Bagenal, 1978):

$$K = 10^5 \times RW/SFL^3$$

where RW = whole body wet weight in kg; SFL = length in cm, the factor 10^5 is used to bring K close to unity; and 3 is the volume of the fish corresponding to 'ideal' or isometric growth.

To make initial diagnoses and visualize the third data set, scattergrams were used before conducting any statistical analyses. Scattergrams provide an overview of the length and weight frequency distribution of wide and fattened ABFT. Dots represent the length or weight frequency of ABFT sampled on 2001 and from 2005 to 2010

Normality test is used to determine whether a data set (SFL and RW) is modelled by a normal distribution. The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population.

Recalling that the population is normally distributed, if the p-value is less than the chosen alpha level (0.05), the null hypothesis is rejected, i.e. the data are not normally distributed population. If the p-value is greater than 0.05, the null hypothesis is accepted, indicating that data came from a normally distributed population.

If data did not come from a normally distributed population, a nonparametric test, the Kruskal-Wallis test, was used to compare more than two sets of scores from different groups. If the probability of the difference between the data set is lower than 0.05, the H_0 must be rejected (there are no difference between the means of the samples) and the H_a must be accepted (there is a difference). The samples have come from different populations.

Results

Type of fork length: The relationship that links SFL and CFL is high (r2 = 0.9943) (Fig. 1); however, the results of our evaluation of the round weight highlighted an overestimation by 2.8%-11% depending on the size of the fish”. The average overestimation of the RW is 6.6% when CFL is used**.** This overestimation could be considered as a better estimate of the RW of harvested ABFT (Aguardo-Gimenez & Garcia-Garcia, 2005) (Fig. 2).

Scattergrams: Normally, each sample is a drawn group that possesses the same characteristics as the population from which it comes. This graphical construct is very versatile and gives a good illustration of data, although there have been major changes over time and different sizes of the samples. The major problem with this dataset is reporting bias. Several gaps appear including large and medium fish (150-200 cm) in 2001, 2008, 2009 and 2010 (Fig. 3). For weight, gaps concern large fish (>300 kg) and even those of average weight (approximately 100 kg) for 2001 and 2008-2009 (Fig. 4). This is the index of a weak sampling effort in the range where deficiencies have emerged.

Size composition

The results are indicated in Table 1. The length frequency, based on the relatively low number of fishes sampled in 2001, shows a bimodal distribution with the first modal class higher than the second at 116-130 and 216-220 cm; the minimum size was 96 cm, while the maximum was 318 cm, with an average of 183 cm. It is noteworthy that, during 2001, the fishing activity was

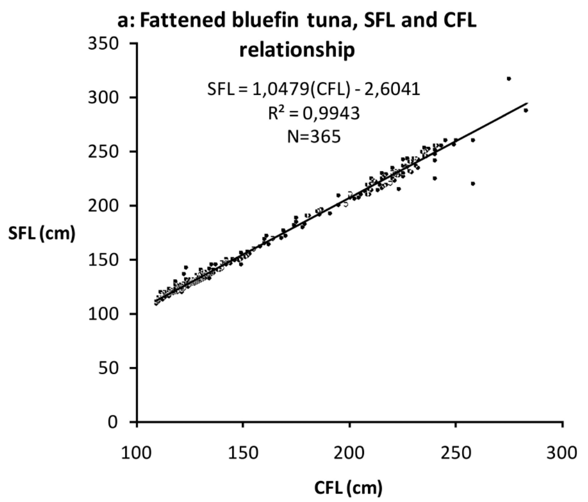

Fig. 1: Relationship of the two types of measures (straight and curved fork length).

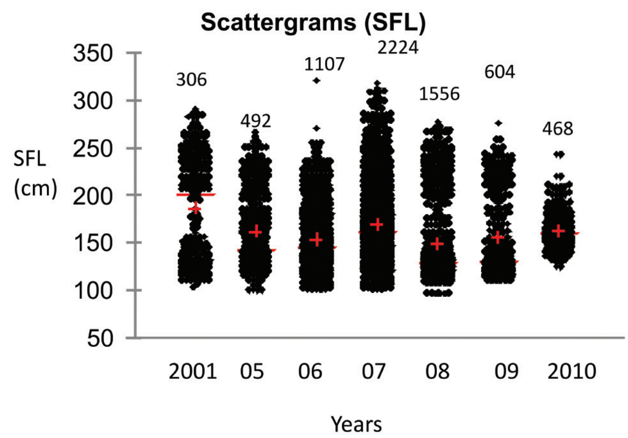

Fig. 3: Scattergrams: Dispersion of SFL in each sample (Wild, 2001 and fattened BFT, 2005-2010).

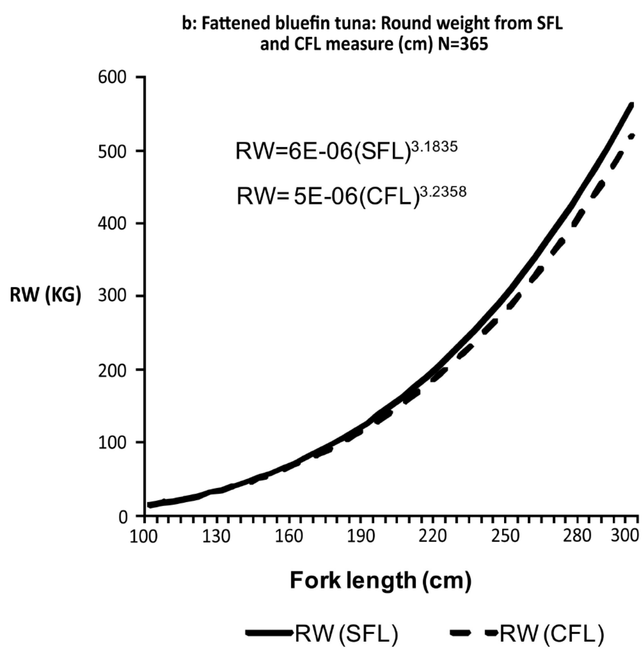

Fig. 2: Round weight (RW) calculated from each type of measure (SFL and CFL).

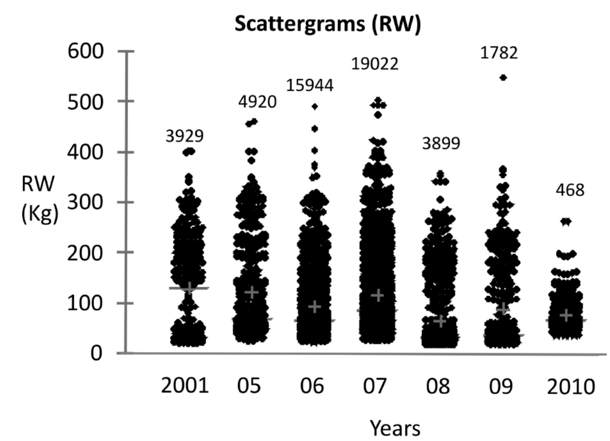

Fig. 4: Scattergrams: Dispersion of RW in each sample (Wild, 2001 and fattened BFT, 2005-2010).

largely targeted at canning. Thus, almost 27.8% of the landed fish were under the size of the first sexual maturity. This percentage was 31.4% in 2009 and only 1% in 2010 (low number of sampled fish). Furthermore, the trend towards targeting increasing number of smaller fish is demonstrated by the decreasing percentage of fish

Table 1. Straight fork length frequency distribution (SFL, cm) of bluefin tuna *Thunnus thynnus* caged on 2005-2010 and landed on 2001 and percentage of fishes beyond 130 cm and up to 200 cm.

SFL (cm)	**Wild fish**		**Fattened fish**											
	2001	**%**	**2005**	**%**	**2006**	**%**	**2007**	**%**	**2008**	**%**	**2009**	**%**	**2010**	**%**
96-100	0		0		3		2		0		0		0	
101-105	2		6		25		36		2		0		0	
106-110	2		4		37		26		3		10		0	
111-115	11	**27.8**	8	**27**	35	**25.8**	40	**21.4**	9	**15.7**	37	**31.3**	0	**0.9**
116-120	21		27		52		95		39		59		0	
121-125	28		33		47		128		82		47		2	
126-130	21		55		86		148		109		36		2	
131-135	11		56		103		185		157		22		16	
136-140	11		57		76		131		97		24		18	
141-145	15		16		60		84		171		26		36	
146-150	17		12		60		122		123		28		42	
151-155	5		14		41		94		124		40		68	
156-160	3		10		71		81		47		31		56	
161-165	1		13		41		108		25		30		52	
166-170	3		11		31		112		69		32		54	
171-175	2		16		27		98		20		12		18	
176-180	3		13		37		73		12		24		38	
181-185	1		9		37		61		5		22		32	
186-190	0		3		30		71		19		7		8	
191-195	2		9		24		74		8		8		8	
196-200	3		19		24		88		11		8		4	
201-205	3		6		32		86		4		6		4	
206-210	10		18		30		79		47		18		6	
211-215	12		8		17		87		45		9		0	
216-220	18		20		16		5		25		17		2	
221-225	5		17		15		4		53		13		0	
226-230	16		10		11		14		49		10		0	
231-235	12		7		13		3		27		8		0	
236-240	10		4		3		6		20		8		0	
240-245	9		1		2		6		47		5		2	
246-250	13		6		8		8		33		3		0	
251-255	10	**47.1**	2	**20.5**	7	**14.5**	7	**16.5**	28	**27.3**	0	**16.7**	0	**3**
256-260	5		1		2		12		11		2		0	
261-265	9		1		2		5		6		0		0	
266-270	3		0		1		7		18		0		0	
271-275	2		0		0		4		3		1		0	
276-280	0		0		0		9		1		0		0	
281-285	6		0		0		8		1		1		0	
286-290	1		0		0		2		4		0		0	
291-295	0		0		0		4		1		0		0	
296-300	0		0		0		3		1		0		0	
>300	0		0		1		8		0		0		0	
Total	**306**		**492**		**1107**		**2224**		**1556**		**604**		**468**	

larger than 200 cm SFL. This percentage decreased from 47.0% in 2001 to only 3% in 2010 (Fig. 5, Table 1).

Annually, the length frequency of fattened ABFT slaughtered after 5-6 months of feeding shows several types of distributions: bimodal for 2005 and 2008, mono-modal for 2006, 2007 and 2010 and trimodal for 2009; however, all distributions clearly showed a substantial increase in juvenile rate (under size of the first maturity: 130 cm [Corriero *et al.,* 2005]) and fish less than 4-years old (Hattour, 2000). This percentage was estimated to be 21.4% in 2005 and increased to 31.3% in 2009 (Fig. 5).

Weight composition

The weight dataset is more important in number (49,964; Table 2) as almost all landed or slaughtered fish are weighed. With regard to the purse seine fishery, the peak was at 31-50 kg (48.6% of landed fish) with a minimum weight less than 20 kg, a maximum at 320 kg and a mean gross weight of 75.7 kg; 73.3% of fish were under the mean weight (75.7 kg) and 76.5% of landed fishes weighed less than 100 kg.

Annual mean weights for fattened fish 124 kg, 83 kg, 94.7 kg, 81 kg, 77.4 kg and 79.3 kg for 2005-2010, respectively, are obviously higher than those of the wild fish (75.7 kg). This decrease is largely because of the fattening process and because purse seiners targeted spawning individuals. Therefore, the peak shifted to 51-75 kg for the fattening process, while the peak was in the range of 31-50 kg for purse seine catch before the fattening process (Fig. 6). For weight distribution, the percentages of the fattened fish weighing less than the mean annual weight were approximately 71%-72%. Years 2009 and 2010 were exceptional, because only 57% and 61% fish were under the mean weight, indicating that the fish caught were becoming increasingly small. The trend in the fish targeted by Tunisian seiners' was clearly demonstrated by the increase in the percentage of the number of

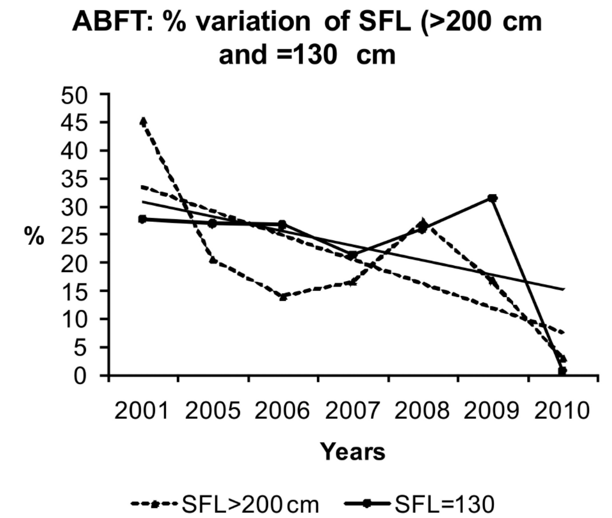

Fig. 5: Variation of SFL percentage of fishes beyond 130 cm and up to 200 cm (2001 and 2005-2010).

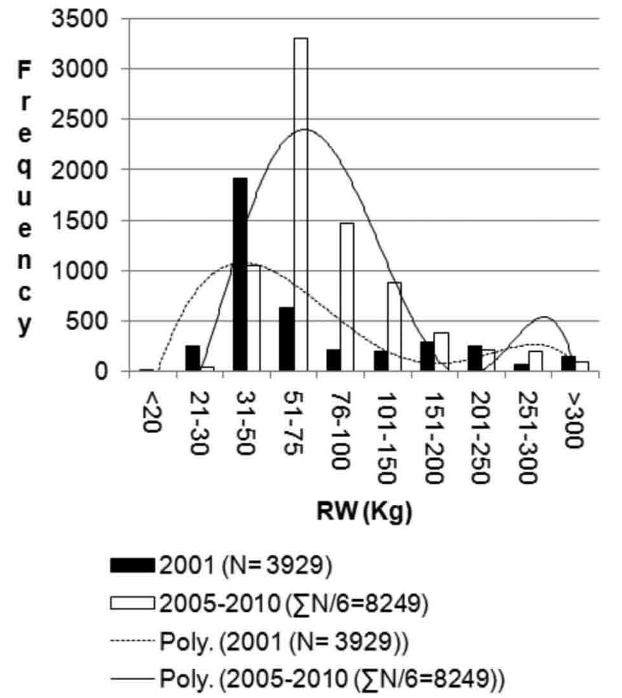

Fig. 6: Weight distribution of ABFT caged on (2005-2010) and landed on 2001.

Table 2. Weight distribution of bluefin tuna *Thunnus thynnus* caged on (2005-2010) and landed on 2001 and percentage of fishes beyond 100 kg.

	Wild		Fattened fish											
Weight Group	**2001**	**%**	**2005**	**%**	**2006**	**%**	**2007**	**%**	**2008**	**%**	**2009**	**%**	**2010**	**%**
<30	258		0		159		0		12		226		0	
31-50	1910	**76.5**	689	**59.9**	2551	**75**	471	**80.1**	2350	**81.4**	190	**94.3**	52	**81.2**
51-75	634		1871		7813		8753		682		490		220	
76-100	203		388		1435		6016		129		775		108	
101-150	192		492		2551		2002		82		106		76	
151-200	290		342		1276		476		201		34		10	
201-250	242		298		159		542		264		38		0	
251-300	58		495		0		571		124		10		2	
>300	142		345		0		190		55		13		0	
Total	3929		4920		15944		19022		3899		1782		468	
Mean weight (kg)	75.7		124		83		94.7		81		77.4		79.3	
Total NB							**49 964**							

specimens with RW under 100 kg. This percentage that was already high in 2001 (76.5%) reached a peak in 2009 (94.3%; Table 2).

Fulton's Condition Factor

The mean condition factors for the wild and fattened ABFT in the Tunisian farms are shown in Table 3. Mean K for wild ABFT was 1.59 and that for fattened ABFT after 5-6 months during 2005-2010 is 2.43, 2.32, 2.15, 1.61, 1.79 and 1.90, respectively. K increased from 1.59 in the wild population to 2.43 in the harvested ABFT. The estimated K in 2008 of dead fish are considerably low during towing to cages (K = 1.02) or during the period of acclimatisation (K = 1.36) and even for the fattening process (from 16 July to 23 September 2008; K = 1.34; Table 4).

Statistical test (third set)

Normality test: (Shapiro-Wilk test): Tables 5 and 6 demonstrate the deviation of SFL and RW data from a normal distribution as the sig value of the Shapiro-Wilk

Table 3. Condition factor (K) for each sampling of ABFT in the port of Sfax (2001) and in Tunisian fattening farms (2005-2010).

Year	**Sampling**					**Fulton's condition factor (K)**				
		SFL (cm)		Corresponding Weight (Kg)		Corresponding K		mean	St dev	Diff/2001
	N	Min	Max							
2001	307	103	290	19	402	1.738	1.648	1.589	0.0884	
2005	492	100	265	24	330	2.400	1.773	2.428	0.2266	+52.79%
2006	1016	100	320	27	448	2.699	1.367	2.319	0.1919	+45.93%
2007	1767	100	318	26	505	2.600	1.576	2.154	0.2323	+35.50%
2008	897	96	276	20	355	2.261	1.689	1.606	0.1352	+1.020%
2009	360	109	275	21	550	1.621	2.645	1.794	0.2387	+12.89%
2010	468	124	242	50	265	2.622	1.869	1.793	0.1392	+13.19%

Table 4. Condition factor (K) for dead ABFT on 2008.

	Sampling					**Fulton's condition factor (K)**				
	N	SFL (cm)		Corresponding Weight (Kg)		Corresponding K		mean K	St dev	Diff/2001
		Min	Max							
2008 (while towing)	217	90	276	8	191	1.097	0.908	1.019	0.1099	-35.9%
2008 (acclimatization)	214	90	276	10	255	1.371	1.212	1.357	0.1450	-14.67%
2008 (while fattening)	1543	90	291	9	285	1.235	1.156	1.341	0.2267	-15.6%

Table 5. Length distribution (Shapiro-Wilk test).

	2001	2005	2006	2007	2008	2009	2010
K-S d	0,17824	0,19482	0,07484	0,0508	0,24228	0,20426	0,05169
p	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,20
Lilliefors p	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
Shapiro-Wilk W=	**0,88923**	**0,92225**	**0,97712**	**0,98493**	**0,80721**	**0,84383**	**0,98495**
p	<,0000	<,0000	<,0001	<,0000	<,0000	<,0000	<,0001

Table 6. Weight distribution (Shapiro-Wilk test).

	2001	2005	2006	2007	2008	2009	2010
K-S d	0,18045	0,16571	0,10319	0,06163	0,23878	0,19773	0,9043
p	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
Lilliefors p	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
Shapiro-Wilk W=	**0,88865**	**0,9160**	**0,96485**	**0,97632**	**0,80529**	**0,86469**	**0,97036**
p	<,0000	<,0000	<,0001	<,0000	<,0000	<,0000	<,0000

test is below 0.05. The Kruskal-Wallis Test does not assume normality in that case. Thus, a nonparametric test was performed.

Kruskal-Wallis Test: Tables 7-9 indicate that K probability (0.0001) is the probability of the difference between the data set occurring by chance. As it is lower than 0.05, the H_0 must be rejected. Thus, samples come from different populations.

Length distribution of wild fish in 2001 was significantly different from that in 2005, 2006, 2008 and 2009.

Table 7. Kruskal-Wallis Test: (length distribution).

Variable	Observations	Min	Max	Mean	St. Devi
2001	307	103	290	186.1	54.190
2005	492	100	265	161.6	38.708
2006	1016	100	320	152.9	33.396
2007	1767	100	317.6	169	40.918
2008	897	96	276	148.4	42.231
2009	360	109	275	155.1	44.947
2010	468	124	242	162.1	17.338
K (Observed value)		**421.602**			
K (Critic value)		**12.592**			
Df		**6**			
p-value (bilateral)		**< 0.0001**			
alpha		**0.05**			

Table 8. Test de Kruskal-Wallis: (weight distribution).

Variable	Observations	Min	Max	Mean	St. Dev.
2001	307	19.0	402	128.1	96.581
2005	492	24.0	460	121.6	93.148
2006	1016	24.0	492	94	67.078
2007	1767	25.0	505	116.6	81.430
2008	897	19.0	360	66.9	68.439
2009	360	17.5	550	90.6	89.788
2010	468	40.0	265	79.3	30.320
K (observed value)		**760.697**			
K (Critic value)		**12.592**			
Df		**6**			
p-value (bilateral)		**< 0.0001**			
alpha		**0.05**			

Table 9. Test de Kruskal-Wallis: (Fulton condition).

Variable	Observations	Min	Max	Mean	St. Dev
2001	307	1.343	1.901	1.584	0.108
2005	492	1.337	3.088	2.428	0.287
2006	1016	1.367	2.745	2.319	0.235
2007	1767	1.202	2.781	2.154	0.292
2008	897	1.284	2.329	1.606	0.168
2008A	214	1.016	1.887	1.357	0.184
2008Wf	1543	0.804	2.554	1.341	0.293
2008To	217	0.731	1.400	1.019	0.138
2009	360	1.267	2.645	1.794	0.289
2010	468	1.246	2.622	1.793	0.180
K (Observed value)		**5320.750**			
K (Critic value)		**16.919**			
Df		**9**			
p-value (bilateral)		**< 0.0001**			
alpha		**0.05**			

Dunn/two-tailed test for multiple comparisons by pairs show an individualization of 2005 sample. Distribution of the length of wild fish (2001) is similar to those in 2007 and 2010 (Table 10). Meanwhile, length distribution in fish sampled from 2006, 2008 and 2009 are close.

Weight distribution of wild fish in 2001 was significantly different from that in 2008 and 2009. Dunn/two-tailed test for multiple comparisons by pairs shows an individualization of samples of 2008 and 2009. Meanwhile, the weight distribution of wild fish (2001) is similar to that in 2005, 2006, 2007 and 2010 (Table 11). Condition factors were significantly different for almost all the samples. The multiple paired comparisons following Dunn/two-tailed test show a progressive increase in K from stressed to wild fish and those subjected to fattening process (Table 12). This difference was not significant between 2005-2006, 2001-2008, 2009-2010 and 2008Wf-2008A. The latter can be explained by a critical condition in the fish.

Discussion

Scattergrams: In the Mediterranean Sea, the spawning season of ABFT lasts from middle May to early July (Schaefer, 2001; Karakulak *et al.,* 2004). Since ICCAT (the body mandated to monitor and manage ABFT resources) governs the seiners fishing period in the Mediterranean, Tunisian purse seiners are active during June, which is the breeding season of migratory ABFT (Block *et al.,* 2001; 2005; Suzuki & Kai, 2012**)**. The fishing area is the place where spawning ABFT aggregate in large shoals (Fromentin & Powers, 2005; Druon *et al.,* 2011). After spawning, the adults swim back to the Atlantic Ocean. Most juveniles move out into the open ocean

Table 10. Length distribution: Procedure of Dunn/two-tailed Test.

Samples	NB	Sum ranks	Mean ranks	Groups			
2008	897	1742821	1943	A			
2009	360	789289	2192	A	B		
2006	1016	2452856	2414		B		
2005	492	1325662	2694			C	
2007	1767	5310525	3005				D
2010	468	1456440	3112				D
2001	307	1007186	3281				D

Table 11. Weight distribution: Procedure of Dunn/two-tailed Test.

Samples	**NB**	**Sum ranks**	**Mean ranks**	**Groups**			
2008	897	1372873	1531	A			
2009	360	726244	2017		B		
2006	1016	2748107	2705			C	
2010	468	1290531	2758			C	
2001	307	881027	2870			C	D
2005	492	1505892	3061				D
2007	1767	5560105	3147				D

Table 12. Fulton condition (K) : Procedure of Dunn/two-tailed Test.

Samples	NB	Sum ranks	Mean ranks	Groups					
2008To	217	72592	335	A					
2008A	214	308460	1441		B				
2008Wf	1543	2264025	1467		B				
2001	307	769825	2508			C			
2008	897	2311870	2577			C			
2009	360	1252110	3478				D		
2010	468	1654290	3535				D		
2007	1767	8973582	5078					E	
2006	1016	5885611	5793						F
2005	492	3017759	6134						F

W: wild; **F**: Fattened; **A**: Acclimatization; **Wf**: While fattening; **To**: Towing

(Dickhut *et al.,* 2009), but some remain and mature in the Mediterranean waters (Hattour, 1995). This behaviour has been hypothesised, but not proven so far. We believe that Mediterranean demographic ABFT population depends closely on the intensity of reproductive cohorts who crossed the Strait of Gibraltar strengthened by those who have not left the Mediterranean. Possibly, this phenomenon, along with the theory that individual spawning may occur once every 2 or 3 years (Lutcavage *et al.,* 1999), determines the annual demographic composition of the fish caught by Tunisian seiners. The outcome is that different cohorts annually aggregate in a very limited area and for a very short time. Therefore, different size and weight distribution of sampled fish was observed.

Size distribution: Spawning fish are known to congregate in large shoals in areas that should have, on an average, good potential for larval survival and development (Fromentin & Powers 2005; Druon *et al.,* 2011). In case of Tunisia, larger fish are known to occur near the Tunisian-Libyan border. Therefore, fishermen from several Mediterranean countries target these spawning fish according to the requirements of the market (farm condition). Purse seiner fishermen have noted that larger fish often enter this zone early in the season (May-June) and as the fishing season has become shorter than that in the past, this may explain the trend towards catching larger fish in farm landings. We know from traps landing that juveniles do not co-exist with larger tuna. It was observed that small (<20 kg) ABFT, who are no longer outfitter by Tunisian seiners, were common in the shallow Tunisian water. This observation is supported by reports from Tunisian purse seiner fishermen. However, in 2009, a rise was observed in the proportion of fish below the size of the first sexual maturity (31.3%). This is the index of an overexploitation of the species (Table 1).

Our results are inconsistent with those of sampling of ABFT caught in Libyan waters, particularly for the proportion of juvenile fish. According to Tawil *et al.* (2007)**,** the percentage of fishes under first maturity size represent 9.5% of catches in tuna traps and 4.3% in the landing of the long line for 2001 and 2002, respectively. It seems that spawning ABFT behave differently for each fishing technique related to environmental conditions and the migration patterns (Ravier & Fromentin, 2004).

Weight distribution: ABFT have particular adaptations that allow them to achieve a maximum metabolic rate, more than the twice that of other fish (Giménez-Casalduero & Sánchez-Jerez, 2006). In addition, they possess a high rate of food assimilation and conversion, three times more than that of other fish (Stevens & McLeese, 1984). Thereafter, they acquire the capacity to quickly grow in a captive environment. The weight loss that occurs during breeding (as a result of spawning tuna feeding very little or not at all) (Hattour, 2000) is quickly compensated and a substantial increase in the weight is observed. The growth rate is variable, depending on various factors. In Tunisian farms, the observed augmentation is 29%-55% of the initial weight (Hattour & Moussa, in press). The minimum weight gain reported by Tzoumas *et al*. (2010) is 27.2%-32.6% and 33.8%-37.8% for sizes 205-245 cm and 255-295 cm, respectively, during the 6-7 months of fattening process through improvement of condition and fat content of the fish. Nevertheless, the SCRS Committee (ICCAT, 2009) assumed that ABFT held for several months for fattening gain 25% of their capture weight on an average. This increase in weight is obviously reflected by the annual mean weight. The mean weight of tuna was significantly higher for those sampled from fattened tuna (124 kg, 83 kg, 94.7 kg, 81 kg, 77.4 kg and 79.3 kg) than that for those from wild tuna (77 kg). The relative low annual mean for 2009 can be explained by the large amount of 'small fish'; 89% of fish slaughtered are less than 100 kg. These figures highlight how Tunisian purse seiners are focusing on smaller fish in response to a strong market demand.

With increase in fat content, tuna are expected to show increased body weight during farming. Gross weight distribution of fattened fish constitutes a contribution to identify ABFT fattened in Tunisian farms.

Fulton's Condition Factor F: Condition factors of ABFT could be a good method to test annual differences in wild and fattened population condition. K varies with sex, size, season and degree of gonad development (Heincke, 1908). Condition factors are highly related to fat content (Clark, 1928). The variability of K is closely dependent on the physiological status of fish, environmental factors, particularly the availability of food. A local abundance may positively bias Fulton's RW Condition Factor; alternatively, a local scarcity may negatively bias it. Boyd (2008) reported that the mean K for wild ABFT in northeast Atlantic during 1997 decreased from 2.35 in August to 1.91 in October. The decrease could be explained by the scarcity of prey in the international waters of the Northeast Atlantic in the autumn of 1997. In the Gibraltar Strait, Macias *et al.* (2012) reported a mean K between 2001 and 2010 ranging from 1.796 in 2001 to 1.943 in 2007.

Mean K for wild and farmed Tunisian ABFT was 1.59 and 2.2, respectively, after 5-6 months of fattening. These values are consistent with the data set analyzed in Greek water by Tzoumas *et al.* (2010) (1.74 and 2.17, respectively, after 6-7 months). Mean K values differ only slightly from those reported by Aguado-Giménez & Garcia-Garcia (2005) in a Spanish farm (from 1.63 [wild fish] to 1.99 after 5 months in captivity). In the data set analyzed by Galaz (2012), the mean K values ranged from 1.81 in July to 2.12 in February. In Malta, a growth trial conducted with large ABFT for 4 months increased the Fulton's Condition Factor from 1.71 to 2.3 (Deguara *et al.,* 2011). The fattening process in Croatian waters for more 17 months did not indicate an outstanding performance since the mean K for wild or fattened fish remained more or less the same from 1.55 to 1.93 and from 1.62 to 1.97 (Katavic *et al.,* 2002); 1.95 in the wild population and 2.33 in ABFT fattened according to Ticina *et al.* (2007)

The sampling of 2008 was special because it highlights trends in specimens severely stressed having lost a lot of their weight. Therefore the corresponding K, based on dead fish, is low compared to the one of fish that achieved growth under normal conditions (isometric growth).

Conclusion

The length distribution of ABFT sampled for this study is represented by 21.4%-31.3% of sub-adults. Larger individuals, representing 13.9%-45.4% of the individuals, measured up to 200 cm SFL and up to 8 years of age. This percentage has a decreasing trend; it decreased from 45.4% in 2001 to 16.7% in 2009. Finally, ABFT targeted by Tunisian purse seiners during the fattening process are becoming smaller and smaller, and the percentage of specimens weighing less than 100 kg (less than 8 years of age) is increasing constantly (from 60% in 2005 to 88.6% in 2009). This is consistent with the conclusion drawn by ICCAT on BFT assessment that clearly indicated that the spawning stock biomass (SSB) had been mostly declining. Trend in fishing mortality (F) displayed a continuous increase over the time for the younger ages (ages 2-5). In the past 6 years of the fattening process, a small decrease in the mean size and an increase in the amount of specimen under the first sexual maturity size was observed. These can be signs of overexploitation, as the percentage of fish that do not have the chance to spawn is increasing. As seen in Table 5, Fulton's Condition Factor increased from 1% to 52.8% with an average of 26.9% for the 6 fattening years compared with that for 2001. The health of fish that died during towing, acclimatisation and even during the process of fattening have negatively biased Fulton's RW Condition Factor. This later decreased from 14.7% to 35.9% with an average of 22.1% for 2008 during the fattening process. The implementation of recent regulations through ICCAT recommendations, if followed by Tunisian and other fishing fleet operating in the Mediterranean, will certainly reduce the catch and fishing mortality rates and contribute to preserve this endangered species.

Acknowledgement

We wish to thank all members of the farm administrative team for field assistance. We are grateful to A. Samet for his significant help during the sampled time. This research has been carried by the National Institute of Marine Science and Technology in Tunisia (INSTM).

References

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

Bagenal, T.B., 1978. Aspects of fish fecundity. p. 75-101. In: *Ecology of Freshwater Fish Production*. Gerking, S.D. (Ed.). Blackwell Scientific Publications, Oxford.

Block, B., Dewar, H., Blackwell, S.B., Williams, T.D., Prince, E.D. *et al*., 2001. Migratory movements, depth preferences, thermal biology of Atlantic bluefin tuna. *Science*, 293, 1310-1314.

Block, B.A., Teo, S.L.H., Walli, A., Boustany, A., Stokesbury, M.J.W. *et al*., 2005. Electronic tagging and population structure of Atlantic bluefin tuna. *Nature*, 434, 1121-1127.

Boyd, J., 2008. *The Japanese bluefin tuna longline fishery in the northeast Atlantic: Report of an Irish observer*. Irish Fisheries Investigations No.20/2008. Fishery Science Services, Marine Institute, Rinville, Oranmore, Co. Galway, 46 pp.

Clark, F.N., 1928. *The weight-length relationship of the California sardine (Sardina caerulea) at San Pedro*. Division of Fish and Game, Fish Bulletin No.12. 59 pp.

Corriero, A., Desantis, S., Deflorio, M., Acone F., Bridges, C.R., 2003. Histological investigation on the ovarian cycle of the bluefin tuna in the Western and central Mediterranean. *Journal of Fish Biology*, 63, 108-119.

Corriero, A., Karakulak, S., Santamaria, N., Deflorio, M., Spedicato, D., 2005. Size and age at sexual maturity of female bluefin tuna (*Thunnus thynnus* L. 1758) from the Mediterranean Sea. *Journal of Applied Ichthyology*, 21, 483-486.

Deguara, S., Caruana, S., Agius, C., 2011. Results of a growth trial carried out in Malta with 190 kg fattened Atlantic Bluefin tuna (*Thunnus thynnus* L.). *Collective Volume of Scientific Papers, ICCAT*, 66 (2), 839-844.

Dickhut, R., Deshpande, A., Cincinelli, A., Cochran, M., Orsolini, S. *et al*., 2009. Atlantic Bluefin Tuna (*Thunnus thynnus*) Population Dynamics Delineated by Organochlorine Tracers. *Environmental Science & Technology*, 43, 8522-8527.

Druon, J.N., Fromentin, J.M., Aulanier, F., Heikkonen, J., 2011. Potential feeding and spawning habitats of Atlantic bluefin tuna in the Mediterranean Sea. *Marine Ecology Progress Series*, 439, 223-240.

Fromentin, J.M., Powers, J.E., 2005. Atlantic bluefin tuna: Population dynamics, ecology, fisheries and management. *Fish and Fisheries*, 6, 281-306.

Galaz, T., 2012. Eleven years -1995-2005- of experience on growth of bluefin tuna (*Thunnus thynnus*) in farms. *Collective Volume of Scientific Papers, ICCAT,* 68 (1), 163-175.

Giménez-Casalduero, F., Sánchez-Jerez, P., 2006. Fattening rate of bluefin tuna *Thunnus thynnus* in two Mediterranean fish farms, *Cybium*, 30 (1), 51-56.

Hattour, A., 1995. La pêche aux thons en Tunisie : Analyse démographique du thon rouge (*Thunnus thynnus*) et de la thonine (*Euthynnus alletteratus*) capturés par les madragues. *ICCAT-SCRS-94/108. Collective Volume of Scientific Papers, ICCAT*, 44 (1), 366-377.

Hattour, A., 2000. *Contribution to the study of pelagic fish in Tunisian waters*. Phd. Thesis,. University of Tunis, Tunis. 243p.

Hattour, A., 2003. The purse seine fishing of bluefin tuna (*Thunnus thynnus*) in Tunisia in 2001. *Collective Volume of Scientific*

Papers, ICCAT, 55, 204-216.
Hattour, A., 2005a. The fattening activity of bluefin tuna in Tunisian waters. *Collective Volume of Scientific Papers, ICCAT,* 58, 606-614.
Hattour, A., 2005b. Comments on bluefin tuna trap net catches of Sidi Daoud. *Collective Volume of Scientific Papers, ICCAT,* 58, 622-629.
Hattour, A., 2005c. Preservation of an ancestral fishing technique: The Tunisian trap net of Sidi Daoud and its production of bluefin tuna (*Thunnus thynnus* (Linnaeus, 1758). *Bulletin de l'Institut National Scientifique et Technique d'Oceanographie et de Peche de Salammbo,* 32, 15-22.
Hattour, A., 2009. Demographic distribution of the bluefin tuna fattened in the Tunisian farms during 2005 and 2007. *Collective Volume of Scientific Papers, ICCAT,* 64, 613-632.
Hattour, A., Macias, D., 2002. Bluefin tuna maturity in Tunisian waters: A preliminary approach. *Collective Volume of Scientific Papers, ICCAT*, 54, 545-553.
Hattour, A., Moussa, A., 2013. Biometric relationship and fattening rate of bluefin tuna *Thunnus thynnus thynnus* L.1758 in Tunisian fish farms. *Bulletin de l'Institut National Scientifique et Technique d'Oceanographie et de Peche de Salammbo,* 39, 43-54.
Heincke, F., 1908. Bericht uber die Untersuchungen der Biologischen Anstalt auf Helgoland zur Naturgeschichte der Nutzfische. (1.April 1905 bis 1. Oktober 1907). p. 67-150. In: *Die Beteiligung Deutschlands an der Internationalen Meeresforschung, 4. & 5. Jahresbericht*. Verlag von Otto Salle, Berlin.
ICCAT, 2009. *International commission for the conservation of Atlantic Tunas-Report for biennial period. 2008-09 PART I (2008) – Vol. 2 English version SCRS*. Madrid, Spain, 271 pp.
ICCAT, 2012. *International Commission for the Conservation of Atlantic Tunas-Report for biennial period. 2010-11 PART I (2011) – Vol. 2 English version SCRS.* Madrid, Spain, 269 pp.
Karakulak, S., Oray, I., Corriero, A., Aprea, A., Spedicato, D. *et al*., 2004. First information on the reproductive biology of the bluefin tuna (*Thunnus thynnus*) in the eastern Mediterranean. *Collective Volume of Scientific Papers, ICCAT*, 56, 1158-1162.
Katavic, I., Ticina, V., Franicevic, V., 2002. A preliminary study of the growth rate of *bluefin tuna from Adriatic when reared in the floating cages. Collective Volume of Scientific Papers, ICCAT*, 54 (2), 472-476.
Lutcavage, M., Brill, R.W., Skomal, G.B., Chase, B.C., Howey, P.W., 1999. Results of pop-up satellite tagging of spawning size class fish in the Gulf of Maine: do North Atlantic bluefin tuna spawn in the mid-Atlantic? *Canadian Journal of Fisheries and Aquatic Science,* 56, 173-177.
Macias, D., Báez, J.C., Alot, E., Rioja, P., Gómez-Vives, M.J. *et al*., 2012. Factores de condicion del atun rojo prereproductor capturado en el estrecho de Gibraltar y su correlacion con las oscilaciones atmosféricas 2012- *SCRS/2011/182 Collective Volume of Scientific Papers, ICCAT*, 68(1), 267-275.
Medina, A., Abascal, F.J., Megina, C., Garcia, A., 2002. Stereological assessment of the reproductive status of female Atlantic northern bluefin tuna during migration to Mediterranean spawning grounds through the Strait of Gibraltar. *Journal of Fish Biology,* 60, 203-217.
Ravier, C., Fromentin, J.M., 2004. Are the long-term fluctuations in Atlantic bluefin tuna (*Thunnus thynnus*) population related to environmental changes? *Fisheries Oceanography,* 13, 145-160**.**
Salz, J.F., Van Voorhees, D., Brown, C., Desfosse, J., Schulze-Haugen, M. *et al.*, 2007. Large pelagic survey bluefin tuna length validation assessment. *SCRS/2006/081 Collective Volume of Scientific Papers, ICCAT,* 60 (4), 1035-1056.
Schaefer, K.M., 2001. Reproductive biology of tunas. p. 225−270. In: *Tuna physiology, ecology and evolution.* Block, B.A., Stevens, E.D. (Eds). Academic Press, San Diego, CA.
SCRS, 2010. Report of the 2009 ICCAT working group on stock assessment methods. *SCRS/2009/010, Collection Volume Paper ICCAT,* 65 (5), 1851-1908.
Stevens, E.D., Mcleese, J.M., 1984. Why bluefin tuna have warm tummies: Temperature effect on trypsin and chymotrypsin. *American Journal of Physiology*, 246: R487-R494. PMID:6720923.
Suzuki, Z., Kai, M., 2012. Movement of Atlantic Bluefin Tuna toward the strait of Gibraltar inferred from Japanese longline data . *SCRS/2011/042 Collective Volume of Scientific Papers, ICCAT,* 67(1), 322-330.
Tawil, M.Y., Elmgawshi, A., Shefren, A., Elmargni, A., 2007. Analysis of sex-ratio by length class for bluefin tuna (BFT) (*Thunnus thynnus*) caught by trap nets and LL from Libyan waters 2000-2005. *Collective Volume of Scientific Papers, ICCAT*, 60, 881-905.
Ticina, V., Katavic, I., Grubisic, L., 2007. Growth indices of small northern bluefin tuna (*Thunnus thynnus*, L.) in growth-out rearing cages. *Aquaculture*, 269, 538-543.
Tzoumas, A., Ramfos, A., De Metrio, G., Corriero, A., Spinos, E. *et al*., 2010. Weight growth of Atlantic bluefin tuna (*Thunnus thynnus* L., 1758) as result of a 6-7 months fattening process in the central Mediterranean. *Collective Volume of Scientific Papers, ICCAT*, 65, 787-800.