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

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#### 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 ( $77-124 \mathrm{~kg}$ ) 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; 0805 ; 09-06) and ICCAT's resolution to establish a multiannual 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 $35-40 \mathrm{~m}$, 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 NovemberDecember 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):

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

where $\mathrm{RW}=$ 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 $\mathrm{H}_{0}$ must be rejected (there are no difference between the means of the samples) and the $\mathrm{H}_{\mathrm{a}}$ 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 ( $\mathrm{r} 2=0.9943$ ) (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


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


Fig. 2: Round weight (RW) calculated from each type of measure (SFL and CFL).
and 2010 (Fig. 3). For weight, gaps concern large fish ( $>300 \mathrm{~kg}$ ) 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. 3: Scattergrams: Dispersion of SFL in each sample (Wild, 2001 and fattened BFT, 2005-2010).


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, monomodal 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 $31-50 \mathrm{~kg}$ ( $48.6 \%$ 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 $124 \mathrm{~kg}, 83 \mathrm{~kg}$, $94.7 \mathrm{~kg}, 81 \mathrm{~kg}, 77.4 \mathrm{~kg}$ and 79.3 kg for $2005-2010$, respectively, are obviously higher than those of the wild fish $(75.7 \mathrm{~kg})$. This decrease is largely because of the fattening process and because purse seiners targeted spawning individuals. Therefore, the peak shifted to $51-75 \mathrm{~kg}$


Fig. 5: Variation of SFL percentage of fishes beyond 130 cm and up to 200 cm (2001 and 2005-2010).
for the fattening process, while the peak was in the range of $31-50 \mathrm{~kg}$ 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. 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 | 76.5 | 0 | 59.9 | 159 | 75 | 0 | 80.1 | 12 | 81.4 | 226 | 94.3 | 0 | 81.2 |
| 31-50 | 1910 |  | 689 |  | 2551 |  | 471 |  | 2350 |  | 190 |  | 52 |  |
| 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 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

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 $(\mathrm{K}=1.02)$ or during the period of acclimatisation $(\mathrm{K}=1.36)$ 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 |  |  |  |  |  |  |  |
| $\begin{gathered} 2008 \\ \text { (while towing) } \end{gathered}$ | 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\% |
| $\mathbf{2 0 0 8}$ (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= | $\mathbf{0 , 8 8 9 2 3}$ | $\mathbf{0 , 9 2 2 2 5}$ | $\mathbf{0 , 9 7 7 1 2}$ | $\mathbf{0 , 9 8 4 9 3}$ | $\mathbf{0 , 8 0 7 2 1}$ | $\mathbf{0 , 8 4 3 8 3}$ | $\mathbf{0 , 9 8 4 9 5}$ |
| $\mathbf{p}$ | $<, 0000$ | $<, 0000$ | $<, 0001$ | $<, 0000$ | $<, 0000$ | $<, 0000$ | $<, 0001$ |

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 = | $\mathbf{0 , 8 8 8 6 5}$ | $\mathbf{0 , 9 1 6 0}$ | $\mathbf{0 , 9 6 4 8 5}$ | $\mathbf{0 , 9 7 6 3 2}$ | $\mathbf{0 , 8 0 5 2 9}$ | $\mathbf{0 , 8 6 4 6 9}$ | $\mathbf{0 , 9 7 0 3 6}$ |
| $\mathbf{p}$ | $<, 0000$ | $<, 0000$ | $<, 0001$ | $<, 0000$ | $<, 0000$ | $<, 0000$ | $<, 0000$ |

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 be-
tween the data set occurring by chance. As it is lower than 0.05 , the $\mathrm{H}_{0}$ 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) |  |  | $\mathbf{4 2 1 . 6 0 2}$ |  |  |
| K (Critic value ) |  | $\mathbf{1 2 . 5 9 2}$ |  |  |  |
| Df |  | $\mathbf{6}$ |  |  |  |
| p-value (bilateral) |  | $<\mathbf{0 . 0 0 0 1}$ |  |  |  |
| alpha | $\mathbf{0 . 0 5}$ |  |  |  |  |

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 ) |  |  | $\mathbf{7 6 0 . 6 9 7}$ |  |  |
| K (Critic value) |  | $\mathbf{1 2 . 5 9 2}$ |  |  |  |
| Df |  | $\mathbf{6}$ |  |  |  |
| p-value (bilateral) |  | $<\mathbf{0 . 0 0 0 1}$ |  |  |  |
| alpha | $\mathbf{0 . 0 5}$ |  |  |  |  |

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/twotailed 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 ( $<20 \mathrm{~kg}$ ) 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 (GiménezCasalduero \& 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 $205-245 \mathrm{~cm}$ and $255-295 \mathrm{~cm}$, 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 ( $124 \mathrm{~kg}, 83 \mathrm{~kg}, 94.7 \mathrm{~kg}, 81$ $\mathrm{kg}, 77.4 \mathrm{~kg}$ 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.

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