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# Some Morphometric Relationships in Fattened Bluefin Tuna, *Thunnus thynnus* L., from the Turkish Aegean Sea

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**Abstract:** This study reports Length-Weight (LWR), Length-Length (LLR) and Length-Girth (LGR) relationships of Bluefin Tuna (BFT), *Thunnus thynnus* raised in captive conditions during 18 months in the Turkish Aegean Sea. A total of 702 specimens, 346 males and 356 females were measured for Fork Length (FL) and weighed on the deck of the harvesting ship during December 2009. Fish ranged between 113 cm FL (16.5 kg) and 286 cm FL (355.5 kg) with an average of 171±1.4 cm (84.9±2.4 kg) in both sexes. The LWRs indicated positive allometric growth in both sexes (the mean value of b was 3.193±0.08). Results indicated that the LLRs and LGRs were highly correlated ($R^2$>0.99->0.98, p<0.001). Fulton's condition factor (K) was also calculated for each fork length class for both sexes. K values ranged from 1.30-1.55 (mean: 1.46±0.03) in males and from 1.29-1.51 (mean: 1.44±0.02) in females. The daily feed intake of BFT was 16.7% and according to the girth values, some BFTs (>230 cm FL and 180 kg) were observed to be over-fattened.

**Key words:** Fattened, bluefin tuna, *Thunnus thynnus*, length, weight, girth, Turkey

## INTRODUCTION

The term fattened Bluefin Tuna (BFT) refers to fish derived from capture-based aquaculture. Capture-based aquaculture is the practice of collecting seed material from early life stages to adults from the wild and subsequently growing fish in captivity to marketable size using aquaculture techniques (Ottolenghi *et al*., 2004). Capture based aquaculture has developed due to the market demand for some high value species whose life cycles cannot currently be closed on a commercial scale (Ottolenghi *et al*., 2004).

The number of tuna farms is growing yearly since the first commercial capture-based tuna farm was established in 1979 in Ceuta, Spain. These farms make it possible to supply fresh tuna of any size at any time. Australia, Japan, Canada, Spain, Mexico, Croatia, Italy, Malta, Morocco and Turkey are engaged in this fishery (Ottolenghi *et al*., 2004; Soto *et al*., 2006). Since 2002, capture-based aquaculture of BFT in floating cages has primarily occurred in the Turkish Aegean and Levantine seas.

Although, total stocking capacity of six BFT farms in Turkish waters has exceeded 6000 tons, now a days, total production is approximately 1000 tons due to the annual ICCAT catch quota. BFT have long been commercially exploited in the Aegean and Levantine seas of Turkey. The fish are usually caught by purse-seine, especially between Antalya Bay and northern Cyprus from late winter to early summer in order to supply fish to Turkish tuna fish farms and/or to export to Japan (Percin and Akyol, 2009). It is known that some morphometric relationships in fish may change as a function of environmental conditions and/or physiological status.

Therefore, disparity in these relationships on account of the fattening process in BFT is expected. Since growth, feeding and mobility inevitably differ substantially in wild and fattening conditions. It is also expected that the somatic condition of BFT will change as a result of the fattening process (Aguado-Gimenez and Garcia-Garcia, 2005).

There is some prior information on Length-Weight (LWR) and Length-Length (LLR) relationships of wild BFT (Lefkaditou *et al*., 1989; Karakulak, 1999; Hossucu *et al*., 2001; Sinovcic *et al*., 2004; El-Tawil *et al*., 2004; Aguado-Gimenez and Garcia-Garcia, 2005; Percin and Akyol, 2009) in the Mediterranean.

However, there are only a couple of morphometric relationship studies (Katavic *et al*., 2002; Aguado-Gimenez and Garcia-Garcia, 2005) on captive BFT. Moreover, data on the length-Girth Relationship (LGR) of BFT have not previously been published. Thus, the present study provides the first comprehensive description of the LWRs, LLRs and LGRs of male and female fattened BFT from the Aegean Sea.

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## MATERIALS AND METHODS

BFT were captured by purse-seine in the Turkish Levantine Sea and put in circular floating cages in June 2008. They were then transferred to tuna farms by towingthe cages to the Bay of Ildir, Izmir. Fish became thinner due to unnourishment prior to reaching the sea-cage farm. The cages were conical having 50 m surface diameter, 30 m depth, 30 m bottom diameter and 84 mm stretch mesh size (Percin and Konyalioglu, 2008). These fish were then fed fresh and/or thawed mackerel (*Scomber japonicus*), herring (*Clupea harengus*), Atlantic menhaden (*Brevoortia tyrannus*), gilt sardine (*Sardinella aurita*), sardine (*Sardina pilchardus*), anchovy (*Engraulis encrasicolus*) and horse mackerel (*Trachurus* sp.) in a considerable proportion *ad libitum*, once a day in the morning. Maximum daily feeding rate, the amount of total fresh food per total weight of BFT in each cage, was 16.7%. The feeding period was 18 months from June 2008-December 2009.

In 2009, surface water temperature and dissolved oxygen were measured in the area of the deployed cages by using an Oxyguard Handy Gamma-meter. Measurements were as follows: 22-24°C, 7.8-8.3 mg $L^{-1}$ in Summer, 18-20°C, 8.8-9.0 mg $L^{-1}$ in Autumn, 14-16°C, 9.4 mg $L^{-1}$ in Winter and 17-21°C, 8.6-8.8 mg $L^{-1}$ in Spring, respectively. After fattening for 18 months, BFT specimens were shooted underwater in their cages by lupara gun with 12 gauge shotshells.

They were measured and weighed before processing during the harvesting season in December 2009. A total of 702 fish (346 males and 356 females) were measured (fork length, FL to the nearest±1 cm) and weighed (total body weight, BW to the nearest±1 kg) on the deck of the harvesting ship. After the measurements were taken, they were immediately gutted and their sex was determined by visual inspection.

The LWR was modeled using an allometric function $BW = aFL^b$. The statistical significance level of the coefficient of determination $R^2$ was estimated. The parameters a and b were estimated by least-squares linear regression using the log transformed equation log BW = loga + blogFL where BW was the body weight (g) and FL was the Fork Length (cm). Standard Length (SL), Total Length (TL) and Girths (G1, G2, G3) of the body were also measured to the nearest cm to explore the relationships TL-SL, SL-FL, FL-TL and FL-G1, G2, G3 by linear regression; G1 was girth across the vertical eye diameter, G2 was girth behind the gill-cover and G3 was girth in front of the first dorsal fin (Stergiou and Karpouzi, 2003). The Fulton's condition factor (K) was calculated for each fork length class for both sexes according to the equation $K = (BW/FL^3)\times100$.

## RESULTS AND DISCUSSION

A total of 702 specimens of BFT were obtained during the study, 346 (49.3%) were Males (M) and 356 (50.7%) were Females (F). F:M ratio was 1:0.97. The length frequency distribution indicates that the 130-170 cm fork length classes had the highest number of male and female specimens, respectively (Fig. 1). Fork lengths ranged between 113 and 283 cm with an average of 171±2.0 cm in 346 males and between 113 and 286 cm with an average of 172±2.1 cm in 356 females. LWR study results showed that the calculated allometric coefficient b ranged from a minimum 3.182 (3.151-3.213, 95% confidence limits of b for females) to a maximum of 3.204 (3.173-3.235, 95% confidence limits of b for males). All LLRs and LGRs shown in Table 1, 2 and Fig. 2 were highly significant (F test for model fit, $p<0.001$) with most of the coefficient of determination values being >0.99 for LLRs and >0.98 for LGRs. Fulton's condition factor (K) in relation to size class is indicated in Fig. 3. K values ranged from 1.30-1.55 in males and from 1.29-1.51 in females. The highest condition values of both males and females occurred in the 270 cm size class. Average K values for all males and females were 1.46±0.03 and 1.44±0.02, respectively. There were no significant differences in K (t-test, $p>0.05$) between males and females.

In this study, 702 *T. thynnus* (346 males and 356 females) were measured from a tuna fattening farm after being fed for 18 months in the Aegean Sea. Although a 6 month feeding period is usually applied after fish are captured (Percin and Konyalioglu, 2008), this studied farm employed a longer feeding period to meet the demand of importers for commercial superiority. However, too fat and abnormal fish were slaughtered now and then during the fattening period (T. Bayar, pers. comm.). Fish were between 113 cm FL (16.5 kg) and 286 cm FL (355.5 kg) with an average of 171±1.4 cm (84.9±2.4 kg) for both sexes Aguado-Gimenez and Garcia-Garcia, (2005) similarly

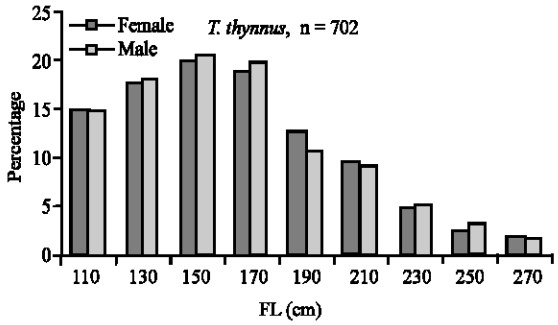


Fig. 1: Length frequencies of male and female *T. thynnus* from a tuna fattened farm in the Aegean Sea

Table 1: Relationships between Total Length (TL), Fork Length (FL) and Standard Length (SL) of fattened *T. thynnus* in the Aegean Sea

| Sex | n | Equation | a | b | SE (b) | $R^2$ |
|---|---|---|---|---|---|---|
| M | 346 | TL = a+bSL | 0.148 | 0.961 | 0.004 | 0.995 |
| | | SL = a+bFL | -0.113 | 1.038 | 0.002 | 0.998 |
| | | FL = a+bTL | -0.030 | 0.998 | 0.003 | 0.997 |
| F | 356 | TL = a+bSL | 0.145 | 0.962 | 0.003 | 0.996 |
| | | SL = a+bFL | -0.107 | 1.035 | 0.002 | 0.998 |
| | | FL = a+bTL | -0.034 | 1.001 | 0.002 | 0.998 |
| M + F | 702 | TL = a+bSL | 0.147 | 0.962 | 0.002 | 0.996 |
| | | SL = a+bFL | -0.110 | 1.036 | 0.002 | 0.998 |
| | | FL = a+bTL | -0.032 | 0.999 | 0.002 | 0.998 |

M, Male; F, Female; n, Number of individuals; $R^2$, coefficient of determination; a, intercept; b, slope; SE, Standard Error

Table 2: GRs of fattened *T. thynnus* in the Aegean Sea

| Sex | n | Length-girth equation | SE (b) | $R^2$ |
|---|---|---|---|---|
| M | 346 | G1 = -2.143+1.772FL | 0.009 | 0.990 |
| | | G2 = -1.171+1.433FL | 0.009 | 0.986 |
| | | G3 = -1.102+1.423FL | 0.010 | 0.984 |
| F | 356 | G1 = -2.156+1.776FL | 0.001 | 0.989 |
| | | G2 = -1.146+1.420FL | 0.009 | 0.987 |
| | | G3 = -1.061+1.404FL | 0.009 | 0.985 |
| M + F | 702 | G1 = -2.149+1.774FL | 0.007 | 0.989 |
| | | G2 = -1.158+1.426FL | 0.006 | 0.986 |
| | | G3 = -1.086+1.416FL | 0.007 | 0.984 |

M, male; F, female; n, number of individuals; $R^2$, coefficient of determination; b, slope; SE, Standard Error

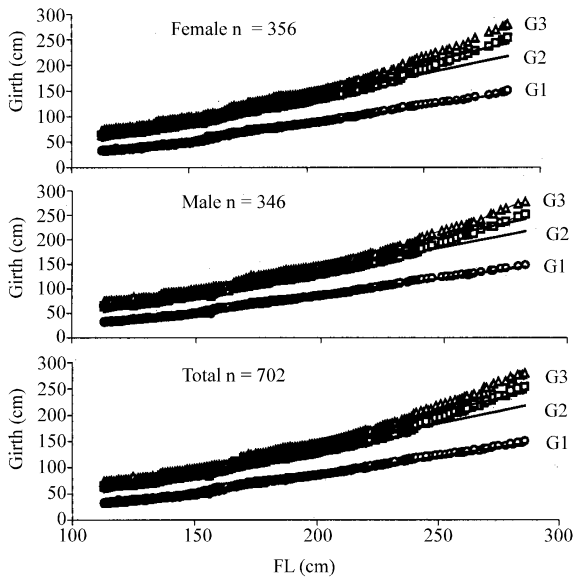


Fig. 2: Relationships between FL and girth across the vertical eye diameter (G1), girth behind the gill-cover (G2) and girth in front of the first dorsal fin (G3) according to sex and all individuals of fattened *T. thynnus* in the Aegean Sea

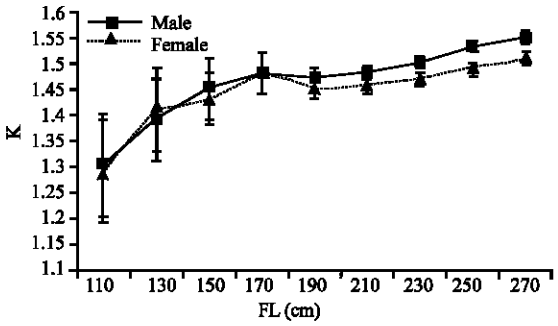


Fig. 3: Mean K values for males (solid line) and females (dashed line) per length (FL) class with ±SD (vertical bars) of fattened *T. thynnus* in the Aegean Sea

reported that the fork lengths of fattened BFTs in the Balearic area varied from 124-282 cm with an average length of 194±2.74 cm (n = 223) whereas there were small BFTs (60-120 cm FL, average: 130.4±15.1 cm, n = 36) in the study of Katavic *et al.* (2002) in the Adriatic. The LWRs indicated positive allometric growth in both sexes (the mean value of b was 3.193±0.08). All allometric coefficients (b) estimated in the present study were within the expected range of 2.5-3.5 (Froese, 2006). The b values were compared with results of other LWRs of fattened BFT studies in the Mediterranean (Table 3). The b values estimated in the study were similar to estimates obtained in other studies.

The parameters of LWRs in fish are affected by a series of factors such as habitat, gonad maturity, sex, stomach fullness, health and within-species differences. Variance in LWRs can be substantial depending on the season, the population, or annual differences in environmental conditions (Avsar, 1998; Froese, 2006).

The relationship between length and weight of the fattened BFT specimens especially in males might be

Table 3: Parameters of LWRs for fattened *T. thynnus* in the Mediteranean

| Researchers | Localitys | Sex | n | Range (FL, cm) | a | b | $R^2$ |
|---|---|---|---|---|---|---|---|
| Katavic *et al.* (2002) | Adriatic sea | M+F | 36 | 60-120 | 0.0050* | 3.29 | 0.983 |
| Aguado-Gimenez and Garcia-Garcia (2005) | Balearic waters | M+F | 223 | 124-282 | 0.0074* | 3.19 | 0.969 |
| This study | Aegean sea | M | 346 | 113-283 | 0.0051 | 3.20 | 0.995 |
| | | F | 356 | 113-286 | 0.0056 | 3.18 | 0.995 |
| | | M+F | 702 | 113-286 | 0.0053 | 3.19 | 0.995 |

*Standardized to cm/g (Froese, 2006)

positively affected by their greater aggression during feeding. The higher condition (K) of males is a good evidence of this state. The positive allometric value in captive conditions is expected due to limited area usage and regular nourishment. The girth figures (Fig. 2), especially G2 and G3 in this study were also evidence of excessive fattening.The girth figure shows that larger (≥230 cm; ≥180 kg) fish tend to diverge from the linear line. Jasper and Evenson (2006) reported that length-girth relationships were important because they allowed the estimation of girth from length measurements and these relationships in conjunction with existing length data could be important tools in the management of gillnet fisheries.

In this study, G2 and G3 of BFT increased more than G1 which is indicative of the size of the cranium. G2 and G3 are indicative of the width of the body due to feeding. These girth values suggest changing of body shape from fusiform to obese. Namely, larger fishes fed before smaller ones because of the feeding hierarchy during the 18 months of captivity (T. Bayar, pers. comm.). Hence, these groups of fishes are naturally obese. At this point, Ottolenghi *et al.* (2004) concluded that the mean daily feed intake of caged BFT was 9.8%.

Whereas, in this study fish were given a daily feed intake of 16.7% suggesting that fishes were over fed. A tuna expert (F. Caglar, pers. comm.) indicated that the Japanese fish markets demand 70-100 kg fusiform fattened fishes morfrom the Turkish BFT farms and that this group ranges between 170 and 190 cm of FL in the research. As a result, the girth values might be a helpful reference for the BFT producers. They might change the in feeding procedures saving feed and labour costs. Also, the volumetric body shape of BFT can be modeled and used to refine feeding programs under captive conditions. It might also be useful to separate big fishes (>200 cm) from the smaller fishes to provide adequate feed to the smaller fish (<170 cm FL and <70 kg).

## CONCLUSION

Finally, this study provides basic information on LWRs, LLRs and LGRs for fattened BFT species that would be useful for fishery biologists/technologists and aquaculturists. Also girth values might give some important clues to both researchers and aquaculturists who study fattening techniques and feeding regimes in tuna farms.

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