

**INVESTIGATIONS ON THE REPRODUCTIVE BIOLOGY OF BLUEFIN TUNA
(*THUNNUS THYNNUS*, L. 1758) IN THE NORTH AEGEAN SEA¹**

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SUMMARY

In September, 1995-June, 1996, research was carried out on 1,382 bluefin tunas (*Thunnus thynnus* L 1758), caught by purse seiners in Çanakkale (Dardanelles), Gökçeada and Bozcaada Islands in Turkish waters in the northern Aegean Sea. In addition, gonado-somatic indices (GSI) of 436 individuals were calculated. Gonads of 36 females were analyzed by the standard histological methods and the diameters of eggs obtained from the gonad samples were measured.

Immature bluefin tunas, which were in the 90-99 cm FL size group made up 50.33% of all bluefin tuna (1,382) examined. Bluefin tuna in the 100-109 cm FL size group (which were just starting to mature) comprised 4.5% of all the bluefin tunas. Bluefin in the 100-119 cm FL size group comprised 29.51% of all the bluefin tunas.

The first sexual maturation for female bluefin tuna seems to start in the 100-109 cm size group, and this bluefin size group was determined hypothetically to be in the age 3 and 4 group.

RÉSUMÉ

Des recherches ont été menées entre septembre 1995 et juin 1996 sur 1.382 thons rouges (*Thunnus thynnus* L. 1758) capturés par des senneurs à Çanakkale (Dardanelles) et dans les îles de Gökçeada et Bozcaada dans les eaux turques du nord de la Mer Egée.

On a aussi calculé l'indice gonado-somatique de 436 poissons. Les gonades de 36 femelles ont été analysées par la méthode histologique standard, et le diamètre des oeufs des échantillons de gonades a été mesuré.

Les thons rouges immatures, de la classe de tailles de 90-99 cm de LF, constituaient 50,33 % de tous les thons rouges étudiés (1.382), ceux de 100-109 cm, qui commençaient le processus de maturité, représentaient 4,5 %, et ceux de 110-119 cm constituaient 29,51 %.

Le processus de maturité des femelles de thon rouge semble commencer avec le groupe mesurant 100-109 cm ; on a postulé que ce groupe de tailles de thon rouge correspondait aux groupes des âges 3 et 4.

RESUMEN

Entre septiembre de 1995 y junio de 1996 se realizaron investigaciones sobre 1.382 atunes rojos, *Thunnus thynnus* L., capturados por cerqueros en las islas Çanakkale (Dardanelos), Gökçeada y Bozcaada, en aguas turcas al norte del Mar Egeo.

Además, se calcularon los índices gonadosomáticos (GSI) de 436 ejemplares. Se analizaron las gónadas de 36 ejemplares hembras por los métodos histológicos estándar y se midieron los diámetros de huevos obtenidos en las muestras de gónadas.

Los atunes rojos inmaduros, entre 90-99 cm FL, constituían el 50,33% de todos los atunes rojo (1.382) examinados, otros, entre 100-109 cm FL, que empezaban a madurar, constituían el 4,5% de todos los atunes rojos, y los peces entre 110-119 cm FL, el 29,51% de todos los atunes rojos.

La primera madurez sexual de las hembras parece iniciarse en el grupo de 100-109 cm FL, y se determinó que este grupo podría estar en los grupos de edad 3 y 4.

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INTRODUCTION

Turkey is surrounded by seas on three sides with a high fishery production potential.

In recent years, there has been an important decrease of the Bluefin tuna catches.

Table 1: Bluefin Tuna Landings in Turkey (ANON, 1980 - 1996)

Year	BFT Catch (ton)
1980	391
1981	565
1982	825
1983	557
1984	869
1985	2230
1986	1524
1987	910
1988	1550
1989	2809
1990	2137
1991	2436
1992	679
1993	1155
1994	998
1995	836
1996	633

In Turkey, Bluefin tuna are caught around Gökçeada and Bozcaada Islands, and in the bays of Saroz, Edremit, Ayvalık, İzmir, Güllük, Fethiye, Antalya and Iskenderun. They are also caught in the Aegean and in the Mediterranean Seas off-shore (Oray, 1994). Bluefin tunas are mostly caught by purse-seiners in Turkey. They are also caught by long lines and pole and lines (Karakulak, 1994).

MATERIALS AND METHODS

In this study, 1382 samples of Bluefin tuna caught by purse-seiners around Çanakkale, Gökçeada and Bozcaada Islands between September 1995 and June 1996 were examined.

During the investigations the fork lengths (FL) and total weights (TW) of the samples were measured.

The first dorsal spines of 460 samples were examined for age determination (Cort, 1991).

The oocyte development of the gonads of a representative sample from each group were also examined visually and under the microscope for the determination of sexual maturation periods. About 15-20 g masses of the female gonad samples from different parts were taken randomly and stored in *Gilson* solution which is prepared from 880 mL distilled water, 100 mL alcohol (60%), 15 mL nitric acid (80%), 20 g HgCl₂, 18 mL acetic acid (added

to sample on slides) (Le Bec, 1983). Then samples were placed on slides; acetic acid was added; and slide preparations were completed. The diameters of oocytes in μ were measured with the inverted microscope and the development stages of oocytes were determined. Three preparations from gonad samples of female individuals were analyzed. Gonad samples obtained from the female BFT were viewed under the microscope and the diameters of approximately 200 eggs were measured.

RESULTS AND DISCUSSION

Length and Weight Frequency Distributions

During the investigations biometrical measurements from 1382 BFT were made and FL and the TW frequency distributions of BFT were determined. A total of 694 BFT in the size group of 90-99 cmFL was the most abundant in catches, and BFT in this interval comprised 50.33% of all measured BFT. This FL interval was followed by 110-119 cm size interval with a percentage of 29.51% among all others. BFT in the size group of 210-219 and 220-229 cm FL were least abundant in catches. However, FL of BFT ranged from 68 to 225 cm (Figure 1).

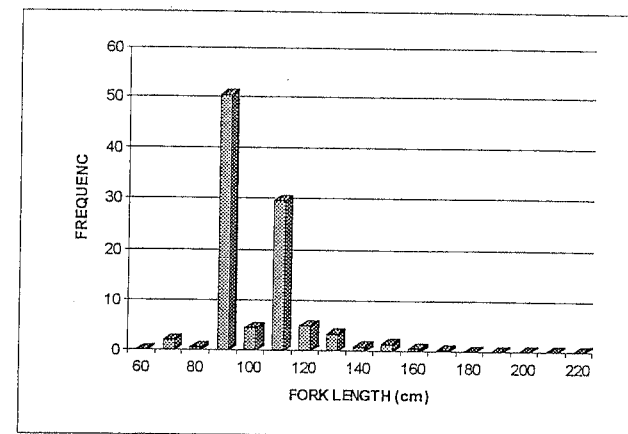


Figure 1. Length frequency distribution of BFT measured during the investigations

It was found that the BFT of 10-19 kg comprised 52.95% of all BFT examined, followed by BFT of 20-29 kg with a percentage of 32.65%. It was determined that the average weight of BFT ranged from 5.5 kg to 150 kg. BFT of 110-119 kg and 150-159 kg were least abundant (Figure 2).

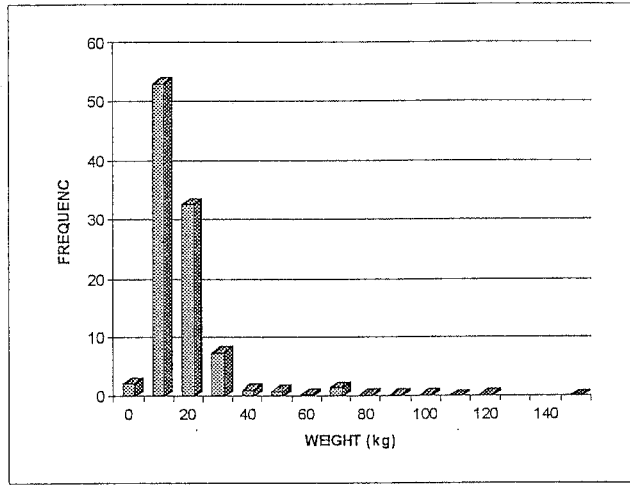


Figure 2. Weight frequency distribution of BFT in 1995- 1996 .

The analyses of length and weights of BFT was performed in Excel and arithmetical mean, standard deviation, variance, variance coefficient, standard error and minimum and maximum length and weight values of BFT are presented in Table 2.

Mean lengths for BFT were calculated as 105.41±0.47 cm and the mean weights were calculated as 21.69±0.36 kg (Table 2).

Table 2. Parameters calculated from the length and weight measurements of BFT

LENGTH	MEAN (cm)	WEIGHT	MEAN (Kg)
X	105,41	X	21,69
S	17,65	S	13,35
S ²	311,35	S ²	178,16
CV	16.74	CV	61.55
Sx	0,47	Sx	0,36
Min.-Max.	68-225	Min.-Max.	5,5-150

The relationships between the length and weight values were determined to be exponential. This relation is shown in Figure 3.

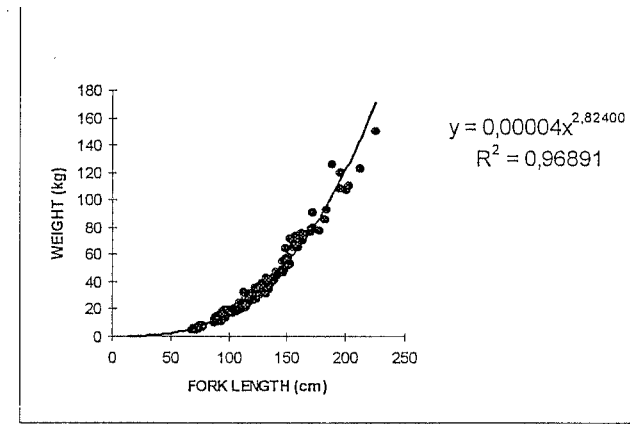


Figure 3. The regression between the length and the weight measurements of BFT

It is interpreted from the regression line that there is a strong and positive relationship between the length and weight of BFT and this is clearly seen in the values of correlation coefficient which is calculated as 0.9843.

Length-Age Relation

The first dorsal fin spines of 460 BFT were taken for age analysis and examined BFT were determined to be in the age groups of II and VII (Table 3).

Table 3. Length - Age relation in BFT

FORK LENGTH (cm)	AGE I	AGE II	AGE III	AGE IV	AGE V	AGE VI	AGE VII	AGE VIII
65-69		2						
70-74		14						
75-79		6						
80-84								
85-89			5					
90-94			102					
95-99			51					
100-104			4					
105-109			4	19				
110-114				155				
115-119				55				
120-124				5	5			
125-129				1	14			
130-134				4	5	1		
135-139					2			
140-144					1	1		
145-149								
150-154							1	
155-159							1	
160-164							1	
165-169								1
170-174								1
N		22	166	239	27	5		1

According to age analysis data, the percentages of 4.79% for II. age group, 36.09% for III. age group, 51.96% for IV. age group, 5.87% for V. age group, 1.09% for VI. age group and 0.22% for VII. age group were calculated. BFT individuals in the age group of IV were the most abundant among others.

Reproductive Biology

The sex ratio of males to females (M:F) slightly differed according to months (Table 4). The M:F ratio in April was 0.92.

Table 4. Sex ratios (M:F) of BFT by months

MONTH	SEX	N	SEX RATIO
FEBRUARY	MALE		
	FEMALE	2	
MARCH	MALE	22	0,92
	FEMALE	24	
APRIL	MALE	159	0,92
	FEMALE	173	
MAY	MALE	19	1,27
	FEMALE	15	
OCTOBER	MALE	2	0,34
	FEMALE	6	
DECEMBER	MALE	5	0,5
	FEMALE	10	

GSI (Gonadosomatic Index) values of 206 male and 230 female BFT individuals were calculated. Maximum, minimum and mean GSI values obtained for female BFT are shown in Table 5, and those values obtained for male BFT are shown in Table 6. GSI values calculated for male and female BFT by months are presented in Figures 4 and 5. Due to of limited and insufficient gonad samples from each length-group, gonads from the male BFT were not analyzed.

Table 5. GSI values for female BFT

MONTH	G S I			
	MAX	MIN	MEAN	SE
FEBRUARY	0,459375	0,45938	0,483973	0,024598
MARCH	0,812676	0,248	0,595481	0,037047
APRIL	1,47619	0,2125	0,663835	0,016088
MAY	1,330612	0,31111	0,691623	0,060182
OCTOBER	1,004878	0,05714	0,328336	0,144559
DECEMBER	0,680851	0,371429	0,532031	0,034385

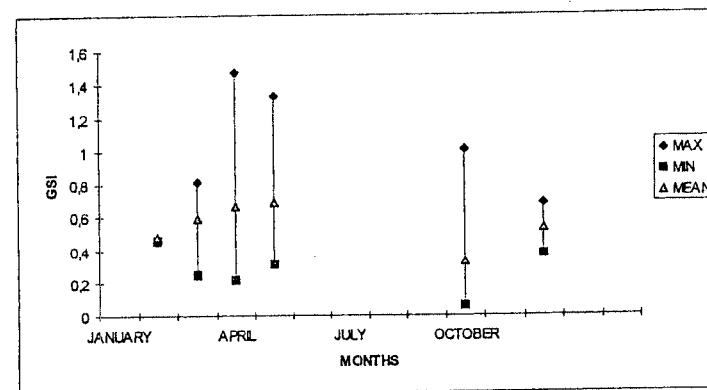


Figure 4. GSI values for female BFT by months

Table 6. GSI values for male BFT

GSI	MAX	MIN	MEAN	SE
MARCH	0,308571	0,08888	0,183008	0.01045
APRIL	1.309523	0,057143	0,306399	0.01149
MAY	1,407143	0,165079	0,494835	0.06996
OCTOBER	0.1625	0.153846	0.158173	0.00432
DECEMBER	0.172973	0.08	0.136971	0.01947

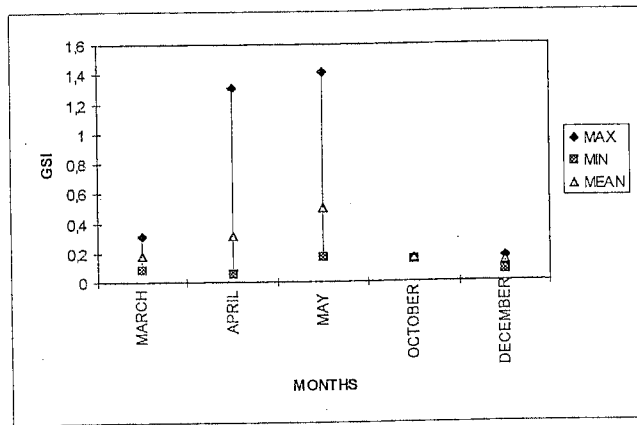


Figure 5. GSI values for male BFT by months

Gonads of BFT were analyzed visually and microscopically. Oocytes obtained from the gonads of BFT caught in April could not be observed visually because these gonads were thought to be immature and did not start to mature yet. Smaller BFT individuals just completing the maturation had dark reddish color, and quite narrow and capillary structures.

BFT more than 80 cm are easily sexed visually by gonad observance. In the other hand, gonads of female mature BFT had a light yellowish color and those gonads were covered by capillaries.

Gonads obtained from male BFT were pinkish-white in color and rigid in structure. Male BFT caught in the period from April to the middle of the May did not spread sperm by squeezing the gonads gently.

Representative gonad samples obtained from 36 females BFT were examined under the microscope and the oocyte diameters were measured. All examined gonads for each length group and their maximum, minimum, and mean oocyte diameters are shown in Table 7.

Table 7. Diameters of eggs measured in μ for female BFT

Length Range (cm)	N	Min.	Max.	Mean
90-99	2	50	100	60
100-109	2	100	230	170
110-119	18	100	240	150
120-129	1	100	260	150
130-139	1	100	250	160
140-149	2	130	420	200
180-189	6	100	250	150
190-199	4	100	250	165

Table 8. Fork length - Weight relations of BFT captured from the various waters

INVESTIGATION	a	b	r	LENGTH RANGE (cm)
A. Srouf (1994) MOROCCO	1.8×10^{-05}	3.0096	0.97	115-290
H. Fushimi (1995) GIBRALTAR STRAIT	7.6416×10^{-6}	3.1316	0.96	180-280
H. Fushimi (1995) MOROCCO (MED.)	1.0106×10^{-3}	3.1726	0.99	36-72
O. Relini (1995) LIGURIAN SEA	0.00005	2.7266	---	50-180
Rodriguez Roda (1964) SPAIN	1.90×10^{-3}	3.00	---	25-279.5
W. H. Bayliff (1994) PACIFIC OCEAN	1.82335×10^{-9}	3.3976	---	
THIS INVESTIGATION NORTH AEGEAN SEA	0.00004	2.8240	0.98	68-225

Serna et al., (1996) investigated the ovarian cell development of BFT. Reporting four growth stages for BFT. Immature oocytes in stages 1 and 2 stucked to each other closely; Oocytes in stage 3 started to mature having a great number of capillaries. The oocytes in stage 4, being fully developed and considered to be mature and nuclei pointing towards and/or already migrating to the pole of the oocytes and the vacuoles being fused.

Rivas (1954) reported that the oocyte diameters of mature female BFT caught in May and June ranged from 700 to 1100 μ .

According to the oocyte diameters of female BFT measured in this investigation, the female BFT in the fork length group of 90-99 cm had the oocytes with a mean 60 μ diameter which was lower than the oocyte diameters of BFT in the length group of 100-199 cm.

Those individuals in the size group of 90-99 cm are considered to be immature and the oocytes of the individuals are determined to be in the oocyte stage of 1. In addition, female BFT in the size group of 100-199 cm had the oocytes in the stages of 2 and 3 and the maturation of oocytes are considered to start to mature in April.

During this study, mature oocytes in stage IV were not observed.

Consequently, the size at first sexual maturity for BFT were determined to be 100-109 cmFL and the BFT in this length stage were determined to be in the ages of III-IV.

Lafaurie and Vallon (1979) reported that female BFT in the FL of 91-95 were immature, and the male and female of 113-117 cm started to mature. The result of their investigations is parallel to our findings.

An investigation conducted in the Japanese Sea showed that the reproduction occurs at the age of V and the FL at this age was 150 cm and total weight of BFT was determined to be 60 kg (Harada 1980).

Hirota et al., (1976) investigated the reproduction of BFT in Pacific Ocean, and reported that the female individuals at age III were 1353 mm and males at age III were 1190 mmFL.

Differences in the age and FL of BFT among above mentioned investigations are due to such characteristics as temperature, salinity, food availability and the environment. The results of the investigation carried out in the Mediterranean Sea are quite similar to our findings in terms of age at first sexual maturity.

Gonads from the male BFT were not analyzed because of insufficient gonad samples from each length groups. The percentage of BFT examined with immature oocytes and oocytes just starting development in this research was 84.34%. These BFT were in the size group of 90-99 cm, 100-109 cm and 110-119 cm.

This shows that undersized BFT were captured by fishermen prior to reaching sexual maturation and preventing reproduction once in a life time and thus having a negative impact on BFT stocks.

Not many investigations on the reproductive biology of BFT have been conducted in the Black Sea, Aegean Sea, and in the Marmara Sea.

In 1955 and 1956, Slastonenko (1955 and 1956) and Akyüz (1956) report that BFT spawned in July - August in the Black Sea.

However, recent investigations conducted on the reproduction of BFT indicated no signs of reproduction, mainly no eggs and/or larvae of BFT were observed in the Black Sea and Marmara Sea in July, 1995 (Piccinetti-Manfrin, 1995).

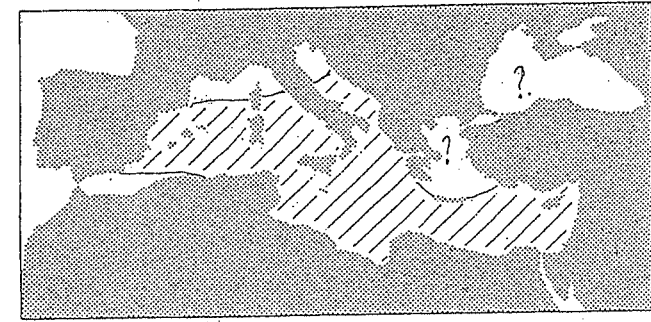


Figure 7. Spawning grounds of BFT in the Mediterranean Sea (Piccinetti et al., 1994)

Research with emphasis on the spawning grounds and spawning time of BFT in the region should be carried out in the Aegean Sea.

More research on the reproductive biology and behavior of BFT in waters surrounding Turkey is needed.

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