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SEX, AGE AND GROWTH OF THE SPURDOG (*Squalus acanthias* LINNAEUS, 1758) IN THE SOUTHEASTERN BLACK SEA

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Abstract: This study was carried out in order to identify sex, age and growth of spurdogs (*Squalus acanthias*) sampled from the southeastern Black Sea between September and october 1991. It was found that the males predominated and the age of this species ranged between I and XIV, with a dominance of age VIII for both sexes. The length-weight relationship was described as $W = 0.0040 * L^{2.95}$ and the mean annual growth rates in length and weight were 7.2 cm and 540.1 g, respectively. Von bertalanffy growth parameters were also calculated as $W_\infty = 12021$ (g), $L_\infty = 157$ (cm), $K = 0.12$ (year^{-1}) and $t_0 = -1.30$ (year).

Keywords: Southeastern Black Sea, age and growth parameters, spurdog (*squalus acanthias*).

1. INTRODUCTION

The spurdog is most frequently found in the mediterranean and the Black Sea (Wheeler, 1969). The annual landings of cartilaginous species by the former USSR, Romanian, Bulgarian and Turkish vessels from the Black Sea rose from 8,314 metric tons in 1980 to 12,472 metric tons in 1983. After 1983, annual landings of these species started to decrease, dropping from 8,359 metric tons in 1984 to 3,928 metric tons in 1991 (GFCM, 1993). While the above - mentioned figures pertain to several cartilaginous fishes, it is most probable that the present catch statistics obtained for turkey and the former USSR are mainly comprised of data for the spurdog. In Turkey, there are no separate catch statistics on the spurdog, but considerable effort has been made by Turkish fishermen to catch this species using gill-nets and entangling-nets along the neritic waters of the Black Sea especially towards the Georgian border with Turkey (personal observations).

While considerable potential exists for spurdog fisheries in riparian countries, there is no comprehensive study on this species in general, only a few specific studies. Amongst the latter, Svetovidov (1964) has reported only the maximum length and age while Ivanov & Beverton (1985) outlined their bio-ecological characteristics and Slastanenko (1956) gave some biological information of this species. The distribution and abundance of spurdogs has been studied by Kutaygil & Bilecik (1977; 1979), who observed that this fish occupied the second and/or third order among the demersal fishes along the western and middle Black Sea coast of Turkey. There is no additional information about the spurdog from the black sea in general and especially from the Turkish Black Sea coast. The other studies are related solely to the distribution (Aksiray, 1987) and abundance of this species (DBT-D.E.U., 1986; Samsun BL. MD., 1984 and Bingel et al., 1993).

The present study describes the length-weight relationship, Von Bertalanffy growth parameters, and the age composition of spurdogs from the southeastern Black Sea coast of Turkey.

2. MATERIAL AND METHODS

Material was collected from 21 stations located along the southeastern Black Sea coast (Fig. 1). The cruise was performed between September-October 1991 and covered the coastal strip using a depth range of 0-100 m.

A bottom trawl with a small mesh size (28 mm in stretched form) was used for the sampling. Trawling time was restricted to a 30 minute period or less due to the unsuitability of the bottom topography.

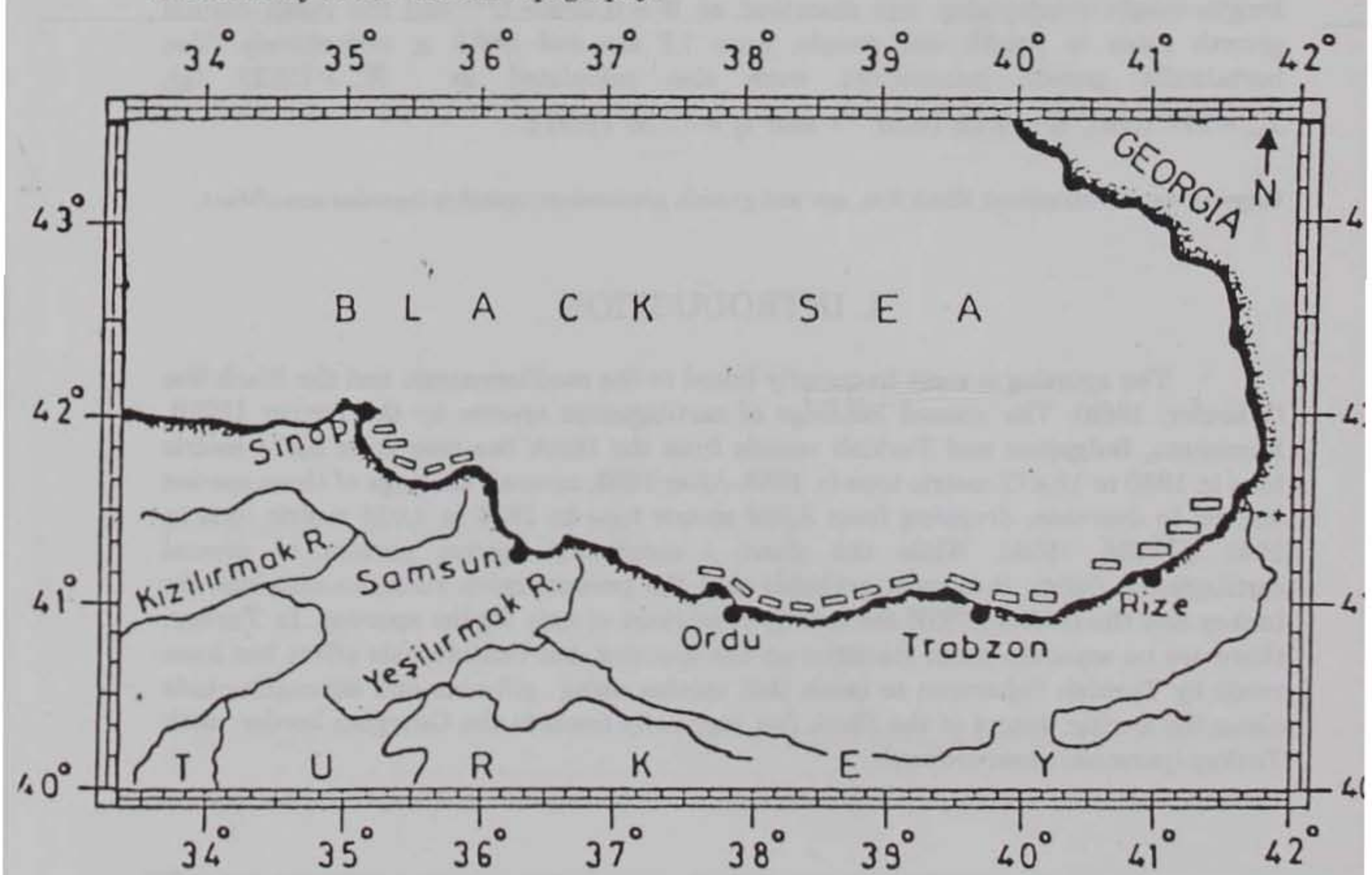

Figure 1. Location of the sampling stations along the southeastern Black Sea coast.

The trawled fish were sorted by species. Sex was differentiated by direct examination of the claspers of males with the naked-eye. For age determination, both the anterior and posterior spines were removed by cutting horizontally just above the notochord, the anterior spine being used only as a check. Rings that were elevated from the spine's surface and were complete on both sides of the spine were considered to be annuli. The number of annuli was determined from the alternating transparent and opaque zones on the spine surface as described by Holden & Meadows (1962), Ketchen (1975), Sosinski (1976) and Beamish & McFarlane (1985). If the tip of any spine was worn then the number of missing annuli was estimated using the procedure of Ketchen (1975) and added to the annuli count to produce an estimated age. Von Bertalanffy growth equations for length and weight were used to estimate of individual growth rate. The Ford-Walford plot technique as described by Sparre & Venema (1992) was applied to calculate of Von Bertalanffy growth constants. The reliability of these growth constants was tested applying "Munro's phi prime values (Θ')" together with the *t* test as described by Sparre & Venema (1992).

The total length of each fish was measured to the nearest centimeter, and weight was determined using a balance with accuracy to the nearest *g*. The fish abdomen was cut with a knife from anus to throat after which the gonad were removed. The external appearance and description of ovarian eggs, and the development of claspers in relation to pelvic fins were reported for the assessment of maturity. Maturity stages of both sexes were divided into three categories, namely immature, maturing and mature as described by Jones & Geen (1977) and Holden & Raitt (1974). The length intervals for both sexes were divided into three major categories considering the length range of immature, maturing and mature individuals. The number of specimens analyzed for each length category and sex are given in Table 1:

Table 1. The minimum (min) and maximum (max) total length measurements (cm) and number of specimens examined (n) for each length categories and sex.

SEX	IMMATURE MIN-MAX (n)	MATURING MIN-MAX (n)	MATURE MIN-MAX (n)	EXAMINED FISH)
MALES	32-66 (28)	65-95 (21)	69-121 (119)	168
FEMALES	37-70 (37)	71-100 (33)	75-136 (90)	160
OVERALL	32-70 (65)	65-100 (54)	69-136 (209)	328

3. RESULTS AND DISCUSSION

3.1 Sex Ratio

A total of 328 spurdog were sexed. A summary of the share of immature, maturing and mature specimens in the overall sample of males and females is given in Table 1 for the studied period. The sample was composed of 17% and 23% immature, 12% and 21% maturing, and 71% and 56% mature males and females respectively. Mature individuals were predominant (>56%) for both sexes followed by immature and maturing individuals. This result implies that older spurdogs are distributed in shallower water than the younger specimens, as stated by Wheeler (1969) and Compagno (1984) for the spurdogs of British waters. According to these authors, the shoals of the spurdog show an irregular movement, although the mature females regularly migrate into shallow water to give birth to their young.

The overall sample examined contained slightly more males making up 51.2% of the specimens, which was not significantly different from a 1:1 sex ratio (χ^2 test, $p>0.95$). This is in good agreement with the result (52.8%) given by Kutaygil & Bilecik (1979) for spurdogs examined in the same area. Whilst the share of males was found to be higher in the present study, a slight (qualitative) predominance of females was found by Sosinski (1976) whereas an equal contribution by both sexes was observed by Gauld (1979) for the North Sea and Scottish-Norwegian spurdog stocks, respectively.

3.2 Age Composition

The sample as a whole was found to consist of individuals ranging from age I to XIII and I to XIV in males and females respectively. In older individuals, age determination was extremely difficult due to their annual increments being small so that the rings tended to fuse. The mean age was calculated to be VIII years old for both sexes. It was observed that most of the fish were contained within three age intervals namely I-V, VI-VII and VIII-XIII in males; and I-VI, VII-X and XI-XIV in females. The length and number of fish at each age according to sex is shown in Fig. 2. Individuals older than age VII were mainly represented by both sexes, and IX - year - old individuals predominate the pooled data. As seen from the Figure, males and females were of equal abundance in the age groups I, II and III and also up to the age group VII. However, the older age groups were dominated by females due to the young being born during the sampling period at a depth of less than 90m (Ivanov & Beverton, 1985).

3.3. Growth in Length

In order to study spurdog growth in length, the mean length for each age group was calculated separately and overall for both sexes. The results of these calculations are in Fig. 2.

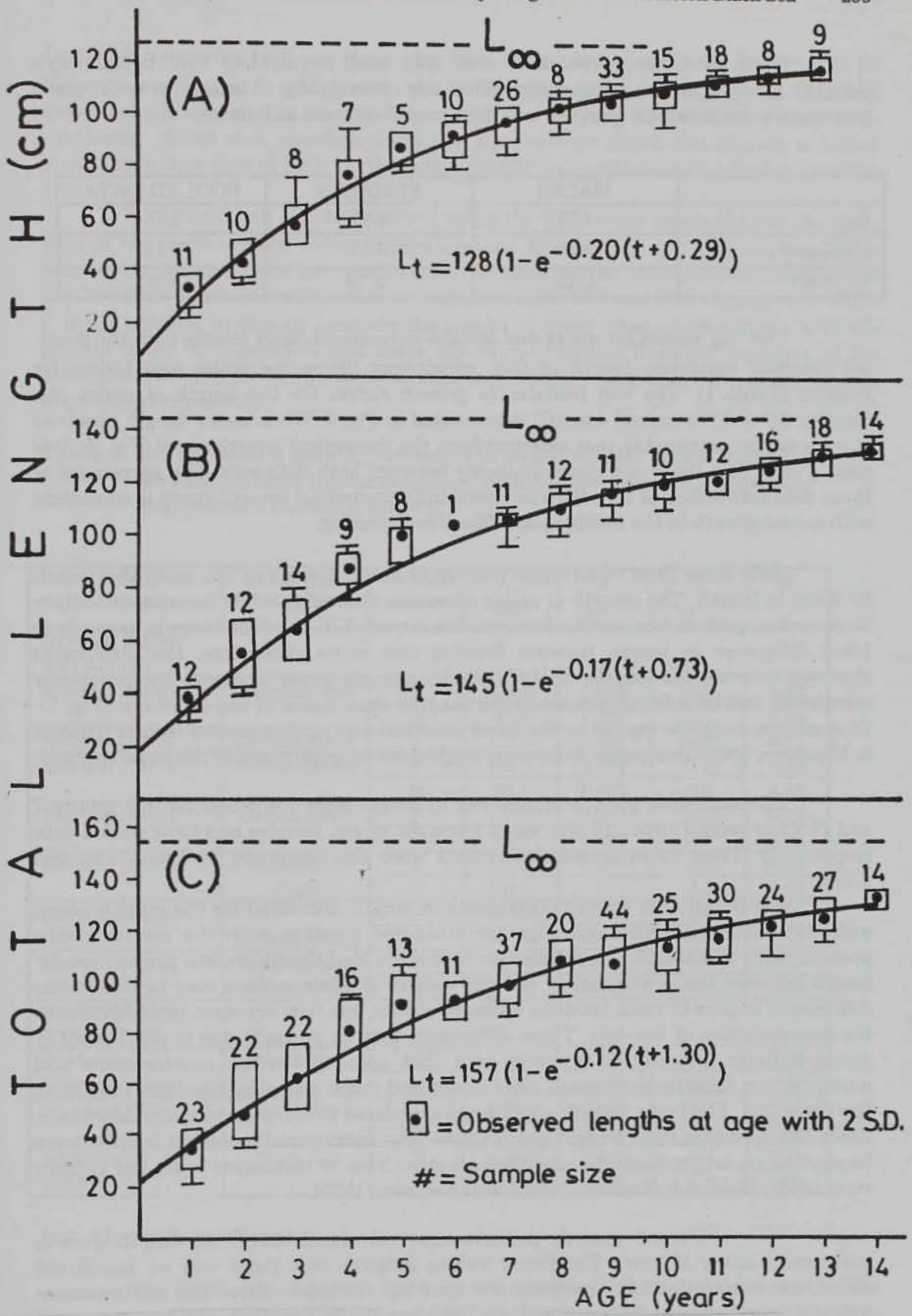

Figure 2. Von bertalanffy growth curves in the length of males (A), females (B) and their overall data (C).

Each of these three data sets was used to calculate Von Bertalanffy's (length) growth curve parameters. The von Bertalanffy length growth curve parameters computed for each sex and their pooled data are as follows:

	MALES	FEMALES	POOLED DATA
L_∞	128	145	157
$K(\text{year}^{-1})$	0.20	0.17	0.12
$t_0(\text{year})$	-0.29	-0.73	-1.30

The L_∞ values for males and females correspond fairly closely with the greatest observed maximum length of fish, which was 121cm for males and 136cm for females (Table 1). The von Bertalanffy growth curves for the length of males (A), females (B) and the overall data (C) is presented in Fig. 2. When mean length observed at each age is compared to that obtained from the theoretical growth curve (Fig. 2), it is clearly seen that there is a close similarity between both data sets. The agreement of these data sets indicates that the von Bertalanffy theoretical growth curve is consistent with actual growth in the southeastern Black Sea spurdog.

Both sexes grow at an equal rate up to about 5 years of life when they reach 80-90cm in length. The growth of males decreases thereafter while females still attain large annual growth increments. For instance in year XIII'th of life there is as much as 10cm difference in length between females and males. Therefore, the differences observed between the lengths of the sexes for any age group is due to the previously mentioned fact that females reach larger lengths than males of the same age (Fig. 2). This situation may be caused by the usual genetical and environmental factors (Holden & Meadows, 1962) that cause different growth rates between sexes of the same species.

The maximum growth increments in length were computed for age groups I and II. They were 17.9cm, 16.9cm and 13.4cm for males, females and their pooled data respectively. Their mean growth increments were also computed as 7cm, 7.4cm and 7.2cm.

von Bertalanffy growth coefficients in length calculated for the northwestern and northeastern Atlantic spurdogs are presented together with the results of the present study in Table 2. The differences in the von Bertalanffy growth parameters for length between the present study and the results of other authors may be due to the differences in growth rates between different stocks, but they are most probably due to the interpretation of the data. These differences may be partially due to differences in ageing criteria, however it is easily seen that spurdogs in the northwestern and northwestern Atlantic grow much more slowly and reach a smaller size than they do in the Black Sea. The large growth coefficients calculated in the present study denote the Black Sea spurdogs have a rapid growth rate. The maximum theoretical lengths were large, though larger than the observed lengths. This is consistent with the pattern reported by Holden & Meadows (1962) and Ketchen (1975).

Overall growth performances calculated from the length growth parameters using Munro's Phi Prime values indicate that there was no significant difference (t test $p>0.05$) between the spurdog samples from the northwestern Atlantic, northeastern Atlantic and southeastern Black Sea. However, the computed

L_∞ and K values for each sex of spurdog from the southeastern Black Sea seem to be higher, not only than those found for the northwestern Atlantic spurdog, but also than those calculated for the northeastern Atlantic spurdog. Therefore, it could be reasonably stated that spurdogs from the southeastern Black Sea display a higher growth rate than that of both northwestern Pacific and northeastern Atlantic spurdogs (Table 2).

This result can also be observed using the "Θ'" values obtained from the spurdogs of the northwestern Atlantic, northeastern Atlantic and the southeastern Black Sea, which increase from the northwestern Atlantic to the northeastern Atlantic and southwestern Black Sea with mean "Θ'" values of 6.58, 7.07 and 8.14 respectively. While it is not possible to directly compare the results of these other investigations with the present study, it is probable that these differences resulted from the exclusion of the older and slower growing members of the stock, which would affect the interpretation of growth performance.

Table 2. von Bertalanffy growth parameters in length and "Θ'" values calculated for each sex from the northwestern Atlantic, northeastern Atlantic and southeastern Black Sea spurdog.

LOCATION & AUTHOR	SAMPLING AREA	SEX	L_∞ (cm)	K (yr^{-1})	t_0 (yr)	Θ'
NORTHWEST ATLANTIC						
Ketchen (1975)	Georgia Strait	F	125.3	0.048	-4.9	6.62
		M	99.8	0.069	-4.7	6.54
Ketchen (1975)	Georgia Strait	F	111.0	0.067	-4.0	6.72
Ketchen (1975)	Georgia Strait	F	129.1	0.034	-7.3	6.34
		M	96.1	0.067	-5.0	6.43
Ketchen (1975)	Hecate Strait	F	125.1	0.031	-10.6	6.19
		M	84.7	0.092	-3.7	6.49
Ketchen (1975)	Washington Coast	F	152.9	0.036	-6.7	6.74
		M	101.8	0.071	-5.2	6.65
Jones & Green (1977)	Georgia Strait	F	128.5	0.036	-6.9	6.39
		M	97.3	0.070	-4.5	6.50
Nammack et al. (1985)	Northeastern Coast of US	F	100.5	0.107	-2.9	6.99
		M	82.5	0.148	-2.7	6.92
NORTHEAST ATLANTIC						
Holden & Meadows (1962)	North Sea	F	101.4	0.110	-3.6	7.03
		M	97.4	0.210	-2.0	7.19
Sosonski (1978)	North Sea	F	137.1	0.054	-4.7	6.92
		M	81.7	0.189	-1.5	7.14
PRESENT STUDY	Black Sea	F	145.0	0.170	-0.7	8.18
		M	128.0	0.200	-0.3	8.09

3.4. Growth in Weight

The mean annual growth increments for males, females and their pooled data was computed as 407.9 g, 555.2g and 540.1 g respectively. The annual growth rate in

weight of males and females was found to be at a maximum between age groups V and VI as 568.5g and 765g, which correspond to 8.9% and 7.5% of their asymptotic weights ($W_\infty = 6401.3$ g and $W_\infty = 10152.2$ g) respectively. It was also computed for the pooled data and found to be at a maximum between year VII and VIII (642.8g), which corresponds to 5.3% of the asymptotic weight ($W_\infty = 12021.7$ g). In young individuals, the annual growth rate of males and females increases as the fish get older till V age group. After completion of year V, annual growth rate starts to decrease as the fish age, because of senescent stress. An increasing trend in growth increment was also observed for the overall data between the age groups of I and VIII; and the maximum increment of 642.8g was found between age groups VII and VIII. After this, the growth increment for the overall data started to decrease. Therefore it is reasonable to state that the fishing of individuals smaller than age group V is not economically viable for stock maintenance.

3.5. Length-Weight Relationship

A total of 168 males and 160 females ranging from 32cm to 121cm and from 37cm to 136cm in total length were weighed to calculate the length-weight relationship for each sex applying the general formula $W = a * L^b$. The constants and correlation coefficients (r) of the relationship calculated from empirical data for each sex and their pooled data are given below:

	MALES	FEMALES	POOLED DATA
a	0.0045	0.0035	0.0040
b	2.92	2.99	2.95
r	0.987	0.993	0.988

The functional regression b-values for each sex and their pooled data were found to be smaller than "3", which implies that the southeastern Black Sea spurdog displays negative allometric growth characteristics. However, the body shape of the females showed more or less isometry with the value of b=2.99, while the males showed negative allometric form with the "b" value of 2.92. Their pooled data was morphometrically positioned between the form of males and females with the value of b=2.95. The small variation in the length-weight relationship of males and females may be a result of different sample size and unequal distribution of sizes within each data set of each sex. Alternatively, non-pregnant females may be lighter due to the inclusion of spent fish, which have a lower condition factor. Since changes in density have important implications for swimming in sharks, females might normally be lighter than males to offset subsequent weight increases due to pregnancy.

Using the coefficient of the length-weight relationship for each sex, it can be stated that spurdog weight increases rapidly with growth. Comparing values of the "b" coefficient, the weight of females is seen to increase faster in relation to length than the weight of males. In fact the females are heavier than the males in any length group (e.g. the females' weight at a length of, say, 110cm is 332g heavier than that of males).

The weight in relation to the length of spurdogs from the southeastern Black Sea is similar to the weight data given by Templeman (1944) for the Newfoundland spurdog. However, the length-weight relationship constants given by Kutaygil & Bilecik (1977) as a=0.027 and b=3.02 and Jones & Geen (1977) as a=0.0017 and b=3.47 for spurdog collected from the southwestern Black Sea coast and for the northeastern Pacific respectively, were higher than those obtained in the present study (a=0.0040 and b=2.95). This may be due to differences in sampling times of the studies reflecting variation in food availability for both regions.

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