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FISHERY ASSESSMENT OF THE RABBITFISH *SIGANUS CANALICULATUS* FROM THE ARABIAN GULF, SAUDI ARABIA

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Keywords: Rabbitfish, *Siganus canaliculatus*, population dynamics, fisheries, Arabian Gulf.

ABSTRACT

This study dealt with the population dynamics of the rabbitfish *Siganus canaliculatus*, one of the economically important fish of the Arabian Gulf fisheries in Saudi Arabia. The length at recruitment (L_r) was 15 cm (total length for both sexes), its calculated weight about 57 g, and the corresponding age at recruitment (t_r) was estimated from Von Bertalanffy equation as 0.86 year for both sexes. The length at first capture (L_c) was 20.0, 21.0, and 20.5 cm for males, females and combined sexes, respectively. Converting these lengths (L_c) to age at first capture (t_c) gave t_c about 1.57, 1.66 and 1.60 years for males, females and combined sexes, respectively. Generally, females of *S. canaliculatus* had larger size and heavier body weights than males. The monthly absolute condition factor (K_c) and relative condition factor (K_n) of *S. canaliculatus* was studied. The maximum age of *S. canaliculatus* was found to be five years in western Arabian Gulf at Saudi Arabia. The young fishes that belong to ages 1-2 years constituted about 60.72, 56.50 % and 58.52 %, while older fishes that belong to ages 3-5 years constituted about 39.28, 43.50 and 41.48 % for males, females and combined sexes, respectively. The computed total mortality coefficients (Z) were 1.48, 1.53 and 1.50 per year and the total mortality rates (A) of 77, 78 and 78 % with survival rates of 23, 22 and 22 % for adult males, females and combined sexes in the fish population. The natural mortality coefficients (M) of *S. canaliculatus* were found to be 0.73, 0.76 and 0.75 per year for males, females and combined sexes, respectively. The fishing mortality coefficients (F) reached 0.75, 0.77 and 0.75 per year for males, females and combined sexes, respectively. The exploitation ratio was discussed in order to help fisheries management in the Arabian Gulf.

INTRODUCTION

Rabbitfish or Siganids are a relatively small family of herbivorous fishes widely distributed in the Indo-Pacific region, from the east coast of Africa to Polynesia, and from southern Japan to northern Australia (Woodland, 1983). They can also be found in the Eastern Mediterranean (Duray, 1990). Of the 30 species recognized by Woodland (1999), only 15 are restricted to coral reefs. Rabbitfishes can have dramatic effects on the distribution and abundance of algae on coral reefs, when juveniles can rapidly remove palatable macroalgae from reef flats during seasonal recruitment events. Fish live at depth that ranges up to 30 meters in territorial seawater, that occur in coral-rich areas in lagoon and seaward reefs. Usually, they live in large schools between Acropora corals where they feed on algae growing on the dead bases of the coral branches. Therefore, they are a fairly cosmopolitan group of fishes (Lam, 1974). *Siganus canaliculatus* the White Spotted Rabbitfish, has a local name 'Safi' in the western coast of Arabian Gulf and ranges from the Arabian Gulf in the west, to China in the north and North-West Australia in the south. This species is found near reef areas as well as river mouths, where they congregate in large schools. *S. canaliculatus* has been popular as excellent seafood with a good price, relatively easy to rear and are thus considered suitable for aquaculture (Lam, 1974; Bryan & Madraisau, 1977; Juario *et al.*, 1985; Hara *et al.*, 1986 a & b). Some studies have been made on the effect of Foxface herbivore nature on reefs. Some authors (El-Sayed and Bary, 1994; Wassef and Abdul Hady, 2001) studied some biological aspects of *S. canalculatus* in the Arabian Gulf. Therefore, the present work reports on the population dynamics of such fish as one of the economically important marine fish in Arabian Gulf fisheries, especially in Saudi Arabia. The study included age composition, growth, mortalities, exploitation ratios, length-weight relationship, condition factor and population parameters. Recommendations of the present work can help to fisheries management and development on scientific bases in Arabian Gulf.

MATERIALS AND METHODS

Random samples of Rabbitfish *Siganus canaliculatus* were collected monthly during the period from January 2002 to December 2002

from the artisanal fishermen, using trammel gillnets at Al-Qatif and Al-Jubil coasts of Saudi Arabia on Arabian Gulf. Fishs were placed immediately in crushed ice and transported to the laboratory, where they were measured and investigated. Date of capture, fish total length (mm) and weight (0.1g) were recorded for each specimen. Fishes were dissected to identify sex and remove viscera then gutted fish weighed to the nearest 0.1g. Length-weight relationship was computed as the following formula: $W = a\ L^b$ (Gulland, 1983), where W= the total weight (g), L = the total length (cm), a and b are constants, whose values were computed by simple regression for the logarithm of the total length and total weight. Absolute condition factor [$K_c = 100\ W/L^3$] and relative condition factor [$K_n = W/W^*$] were computed, where L is the fish length, W is the fish weight and W* is the calculated weight. Scales, otoliths and vertebrae were examined for age reading of *Siganus canaliculatus* and it was found that otoliths and the minute embedded scales were very small and could hardly be seen; and their ring formations were irregular. Therefore, vertebrae were selected as a suitable tool for age determination according to Al-Ghais (1993). The regression analysis was used to determine the relationship between vertebrae radius and the fish total length for both sexes. The back calculated lengths and the weights corresponding to each age group were computed by using FSAS computer programs (Saila *et al.*, 1988) and the annual growth increment was calculated in grams and percentage. The Von Bertalanffy Growth Parameters (VBGP) including length at infinite age (L_∞), growth coefficient (K) and age at which length of fish is theoretically nil (t_0) were determined. Growth in length and weight was expressed in terms by applying (Sparre and Venema, 1992) the Von Bertalanffy equations: $L_t = L_\infty [1-e^{-k(t - to)}]$, and $W_t = W_\infty [1-e^{-k(t - to)}]^b$, where: L_t and W_t are the theoretical length and theoretical weight at age t, the asymptotic weight (W_∞) is the calculated weight of L_∞. The mortality coefficient (Z) was estimated by the linearized catch curve method (Pauly, 1983). Simple annual mortality rate (A) of this portion of the stock was estimated as: $A = 1 - e^{-Z}$ (Ricker, 1975).

The natural mortality coefficient (M) was estimated from Pauly' equation (1980) as: $Ln\ M = 0.8*[-0.0152-0.279\ Ln\ L_\infty +$

0.6543 Ln K + 0.463 Ln T], where: L_∞ and K are VBG parameters. (T) is the mean surface water temperatures of the Arabian Gulf which equals to 25.6 °C (Tharwat, 2003). The exploitation rate (E) of the stock was calculated according to Pauly (1980) as: E = F/Z. where: Z and F are the total and fishing mortality coefficients, respectively. Statistical analysis was applied using the program of SAS, (1990) and the significance of differences between two sexes was tested ($P < 0.05$) with analysis of variance for length weight relationship, condition factor, back-calculated lengths and weights at the different age groups, age frequency, and the total instantaneous mortality (Z). Differences among slopes and intercepts were determined with ANOVA (Schaffer and Elson, 1975).

RESULTS AND DISCUSSION

Description and Classification:

Rabbitfish *Siganus canaliculatus* can be morphologically described as follows: 1) the body shape compressed; 2) the body protected by smooth and small cycloid scales; 3) the snout resembles that of a rabbit; 4) the terminal-small mouth possesses small teeth; 5) the lateral line simple; and 6) the number of spines at the dorsal, anal and ventral fins 13, 7 and 2, respectively. Generally, species are identified based on their shape, fin's equation, color and behavior. The systematic classification of *Siganus canaliculatus* was described according to Duray (1990) and Carpenter *et al.* (1997) as follows: Phylum: Chordata, Subphylum: Vertebrata, Grade: Pisces, Class: Osteichthyes, Subclass: Acteropterigii, Infraclass: Neopterigii, Division: Halecostomi, Subdivision: Teleostei, Superorder: Acanthopterigii, Order: Perciformis, Family: Siganidae, Genus: *Siganus*, Species: *canaliculatus* (Park, 1797).

Length analysis:

The length analysis of *Siganus canaliculatus* revealed that about 80 % of fishes were belonging to length categories of 15 – 28 cm for both sexes. The smallest total length of *S. canaliculatus* that was represented monthly in the catch is selected to be the length at recruitment (L_r) according to King (1998) and was found to be 15 cm total length for both sexes. Its calculated weight is about 57 g for both sexes. The corresponding age at recruitment (t_r) is estimated from Von Bertalanffy equation as 0.86 year for both sexes. The

length at first capture (L_c) is the size at which 50 % of fish retained by the gear. L_c was computed, using the length selection catch curve method of Lee and Baddar (1989) and L_c estimated values were 20.0, 21.0, and 20.5 cm for males, females and combined sexes, respectively (Fig. 1). Converting these lengths (L_c) to the age at first capture (t_c) gave t_c about 1.57, 1.66 and 1.60 years for males, females and combined sexes, respectively. On the other hand, the actual true measured maximum length was found to be 34 and 36 cm total length and maximum total weight was 582 and 673 g for males and females, respectively. The slightly different Lc values between males and females may be attributed to the differential growth rate due to sexual behavior.

Length-weight relationships:

Length-weight relationships of *S. canaliculatus* for both sexes are graphically presented in Figure (2). The present results indicate that the sizes of females were relatively larger than males, where the average total lengths were 20.23 ± 2.84 cm and 21.93 ± 3.75 cm for males and females, respectively. Generally, females of *S. canaliculatus* had heavier body weights than males in relation to length. Total body weight ranged between 54-582 g, with an average of 143.91 ± 20.17 g for males and ranged between 59-673 g, with an average of 165.42 ± 31.62 g for females. Therefore, logarithmic and exponential equations can be derived for describing the length-weight relationship for males and females of *S. canaliculatus* as follows:

Log W = -1.7986 + 3.00 log L or $W = 0.0159\ (L)^{3.00}$

[n = 779, r = 0.9976 for males].

Log W = -1.7904 + 3.03 log.L or $W = 0.0162\ (L)^{3.03}$

[n = 846, r = 0.9987 for females]. Sex differences between males and females were tested by ANOVA and found to be insignificant ($P < 0.05$). Accordingly, data were pooled for combined sexes and one equation was given to represent this relationship as follows: Log W=-1.7959 + 3.02 log L or $W = 0.0160\ (L)^{3.02}$

[n = 1625, r = 0.9989 for combined sexes]. Where W is the total weight of fish (g), L is the total length of fish (cm), n is number of fishes and r is the correlation coefficient. The high values of r indicate a good measure for the strength of these equations and

closeness of observed and calculated values of fish weight. The slope (b) of the linear regression in the present study are in agreement with the other results on the same species (Al-Ghais, 1993; Wassef and Abdul Hady, 2001; Tharwat and Al-Owafier, 2003) and the results obtained by Hashem (1983); El-Gammal (1988) and Bilecenoglu (2002) on *Siganus rivulatus*. where their b value was about 3.0. On the other hand, Lai Man So *et al.* (1999) investigated *Siganus oramin* (*S. canaliculatus*) collected from Tolo Harbour and Victoria Harbour in Hong Kong and outside Hong Kong. They found that average fish weights were 56.3, 33.0, 234.3 g for the three regions, respectively. From the present results and those of Lai Man So *et al.* (1999) it can be concluded that the growth rate and maximum fish size were significantly different for the same species in different habitats. The growth is relatively high in Arabian Gulf that may be attributed to suitable environmental conditions, which lead to high productivity and fish growth. Also, Al Ghais (1993) recorded heavier weights for females than for males in relation to length.

Condition factor:

Condition factor is usually used to indicate the suitability of the environment and to compare between wild and reared fish. The average monthly of absolute condition factor (K_c) and relative condition factor (K_n) of *Siganus canaliculatus* inhabiting the Arabian Gulf are shown in Figures (3) and (4), respectively. The present results revealed that K_c values were fluctuated between 1.15 – 1.48 with an average of 1.29 for males, between 1.20 – 1.52 with an average of 1.34 for females and between 1.17 – 1.50 with an average of 1.32 for combined sexes. The graphical representation for both sexes shows a similar trend of K_c pattern to make two peaks, the first was the highest which occurred in May and the second was moderate which occurred in September. The K_c values began to increase from February to reach a maximum value at May (prespawning) then decreased after May to July (spawning season) particularly for females. Generally, the observed values of K_c in females were relatively higher than males, and no significant differences ($P<0.05$) were found between the two sexes. The values of K_n for males, females and combined sexes of *Siganus canaliculatus* displayed a fluctuation pattern around 1.0 with a relatively high increase values during May and September (Fig.4). The average monthly K_n

fluctuated between 0.97 – 1.02 with an average of 1.00 for males, between 0.98 – 1.04 with an average of 1.02 for females and between 0.98-1.03 with an average of 1.01 for combined sexes. This result is relatively in agreement with the study of Al-Ghais (1993) and Tharwat and Al-Owafeir (2003) on the same species and on *S. rivulatus* (Hashem, 1983; El-Gammal, 1988). Sex differences were tested for the mean values of condition factor to be insignificant ($P < 0.05$). It was also noticed from the present investigation that the values Kc and Kn increased gradually by increasing length. It is well known that the high values of Kc and Kn for fishes are attributed to fat accumulation, fullness of alimentary canal or gonads development, as a result of favorable conditions of the habitat.

Age and growth:

The relationship between fish total length and vertebra radius was logarithmic with no statistical difference ($P < 0.05$) between males and females. These relationships can be described by the linear equations as follows: Log L = 1.072 + 1. 124 Log Vr , with r = 0.9732 for males and Log L = 1.084 + 1.163 Log Vr , with r = 0.9867 for females, where L = total length of fish (cm) , Vr = vertebra radius (mm), and r = correlation coefficient of the regression equation. Consequently, these relationships were used to predict the back-calculated lengths at successive annuli. The rings were validated as being true annuli by marginal increment analysis, where fish were grouped by month of collection and the mean distance from the last ring to the vertebra edge was computed and graphically presented in Figure (5). Only the vertebras of two and three rings were used for this purpose, since they could be read more easily. It is obvious that rings were formed during March each year. The mean back calculated and theoretical growth model of lengths and weights at the end of each year of life for males, females and combined sexes of *Siganus canaliculatus* are summarized in Table (1). It is noticed that both males and females of *S. canaliculatus* can live up to five years in the Arabian Gulf. The assessment of growth rates showed that the growth in length was high during the first year of life, and marked by decreased during older ages. The growth in weight, on the other hand, had showed an opposite trend: as it was very small during the first year and sharply increased from the 2nd through the 4th year of life. Such sequence of growth is logic and is

mostly due to maturation. Females had a slightly faster growth rate than males. The derived formula from Von Bertalanffy growth model for males and females of *S. canaliculatus* was as follows: $L_t = 42.2[1 - e^{-0.28\,(t + 0.71)}]$, for males and $L_t = 41.1[1 - e^{-0.31\,(t + 0.62)}]$, for females, where L_t = fish length at age t (years). Al-Ghais (1993) indicated that the mean standard lengths of *Siganus canaliculatus* in the southern Arabian Gulf. United Arab Emirates during four years were 14.3, 17.1, 20.2, and 22.1 cm for males, 14.3, 17.0, 19.5 and 24.3 cm for females and 14.3, 17.0, 19.8 and 23.2 for combined sexes. There seems a reasonable agreement between the present results and those of Al-Ghais, (1993) with respect to the age groups 1-4, where our results were calculated by total lengths and his results by standard lengths. The Von Bertalanffy growth curves suggest a greater maximum size for females than males. There were no statistical differences ($P < 0.05$) between the mean back-calculated growth and von Bertalanffy growth model of either sex. The growth pattern of some reared siganids (*S. canaliculatus*, *S. vermiculatus*, *S. guttatus*, and *S. rivulatus*) have been described by various authors (Ben-Tuvia *et al.*, 1973; Popper and Gundermann, 1976; Gundermann *et al.*, 1983; Duray and Kohno, 1988). They indicated that these species are fast growing fish. In this study, the growth rate of *S. canaliculatus* inhabiting Arabian Gulf was relatively high and in agreement with them. On the other hand, Westernhagen and Rosenthal (1976) pointed out that the body weight of *S. canaliculatus* in mariculture could attain 150 g for both sexes in their first year of age.

Age composition:

The percentage of fishes of each age group for males, females and combined sexes of *Siganus canaliculatus* was investigated and graphically presented in Figure (6). The diagram indicated that age group (0) was not represented in the catch for both sexes. The age groups 1-5 years constituted 25.03, 35.69, 26.44, 11.17 and 1.67 % for males and 21.51, 34.99, 30.8, 11.23 and 1.89 % for females. Thus, the young fishes that belong to ages 1-2 years constituted about 60.72, 56.50 % and 58.52 % for males, females and combined sexes, respectively. However, older fishes that belong to ages 3-5 years were decreased in the catch and constituted about 39.28, 43.50 and 41.48 % for males, females and combined sexes, respectively (which included fully mature fishes in the catch). These results can

be supported also by the abundance of suitable marketable size of *S. canaliculatus* in the catch of Arabian Gulf all over the year, which indicates that the stock is still exploited at a reasonable level of fishing effort. On the other hand, the present results indicated that *S. canaliculatus* could live up to five years in the western coast of Arabian Gulf, Saudi Arabia, while the same species was found to live for four years in the southern Arabian Gulf, United Arab Emirates (Al-Ghais, 1993). This limited difference in species longevity could be due to the different fishing exploitation levels in the two localities of the Arabian Gulf.

Mortality rates and exploitation ratios:

All estimated population parameters for males, females and combined sexes were shown in Table (2). The catch curves for fully recruited males, females and combined sexes of *Siganus canaliculatus* are presented graphically in Figures (7, 8 and 9) and were used to estimate the total mortality coefficients (Z). It is obvious that the slope of the catch curve was descending for the adult fishes that belong to age older than two years. The computed total mortality coefficients (Z) were 1.48, 1.53 and 1.50 per year for males, females and combined sexes, respectively. That means that the total mortality rates (A) equal to 77, 78 and 78 % with survival rates of 23, 22 and 22 % for the adult individuals of males, females and combined sexes in the fish population. The mean surface water temperature (25.6 ^{0}C) of the Arabian Gulf (Tharwat, 2003) was used to estimate the natural mortality coefficients (M) of *S. canaliculatus*, which were found to be 0.73, 0.76 and 0.75 per year for males, females and combined sexes, respectively. On the other hand, the values of fishing mortality coefficient (F) were obtained from the difference between total and natural mortality coefficients and were equal to 0.75, 0.77 and 0.75 per year for males, females and combined sexes, respectively. The exploitation ratios of fish stock under the current fishing effort represented 0.51, 0.50 and 0.50 yearly for males, females and combined sexes, respectively. It is well known that the exploitation ratio (E) allows to roughly assess whether the stock is overexploited or not, on the assumption that the optimal value of E equals to 0.50. From the above mentioned findings and the size at first sexual maturity "Lm50" that equals to 19 cm total length for the same species at the same localities

(Tharwat, 2004) it can be concluded that the stock of *S. canaliculatus* is still at a suitable level of current fishery exploitation in the Arabian Gulf at Saudi Arabia.

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Table 1. The average back calculated lengths and weights and Von Bertalanffy growth model at the five age groups of *S. canaliculatus*.

Age (year)	Freq.	Growth in length			Growth in weight			Von Bertalanffy growth model	
		Total length, Cm	increment		Total weight, g	increment		Total length, cm	Total weight, g
			cm	%		g	%		
Males:									
1	195	16.0 ± 0.61	16	47.5	65.1 ± 1.14	65.1	10.9	16.1	64.1
2	278	22.3 ± 0.56	6.3	18.7	176.3 ± 1.39	111.2	18.6	22.5	174.5
3	206	27.4 ± 0.72	5.1	15.1	317.2 ± 1.71	140.9	23.5	27.3	312.5
4	87	31.2 ± 0.79	3.8	11.3	472.9 ± 1.92	155.7	26.0	30.9	456.5
5	13	33.7 ± 0.84	2.5	7.4	598.5 ± 2.13	125.6	21.0	33.7	589.0
Total	**779**		**33.7**	**100**		**598.5**	**100.0**		
Females:									
1	182	16.2 ± 0.67	16.2	47.6	74.9 ± 1.19	74.9	10.7	16.2	75.3
2	296	22.7 ± 0.60	6.5	19.1	209.0 ± 1.30	134.1	19.2	22.9	212.3
3	257	28.1 ± 0.71	5.4	15.9	377.3 ± 1.42	168.3	24.1	27.7	380.3
4	95	31.7 ± 0.75	3.6	10.6	556.4 ± 1.80	179.1	25.7	31.3	549.5
5	16	34.0 ± 0.86	2.3	6.8	697.8 ± 2.25	141.4	20.3	33.9	701.8
Total	**846**		**34.0**	**100**		**697.8**	**100.0**		
Sexes combined									
1	377	16.1 ± 0.59	16.1	47.6	70.6 ± 1.13	70.6	10.7	16.2	71.6
2	574	22.5 ± 0.50	6.4	18.9	194.0 ± 1.22	123.4	18.6	22.8	202.5
3	463	27.7 ± 0.66	5.2	15.4	360.4 ± 1.36	166.4	25.1	27.7	363.9
4	182	31.4 ± 0.70	3.7	10.9	532.7 ± 1.65	172.3	26.0	31.4	530.2
5	29	33.8 ± 0.79	2.4	7.1	662.9 ± 1.94	130.2	19.6	34.1	678.8
Total	**1625**		**33.8**	**100**		**662.9**	**100.0**		

Table 2. The estimated population parameters of males, females and combined sexes of *S. canaliculatus* inhabiting Arabian Gulf at Saudi Arabia.

Population Parameters	Males	Females	Combined sexes
M (natural mortality coefficient, yr^{-1})	0.73	0.76	0.75
Z (total mortality coefficient, yr^{-1})	1.48	1.53	1.50
F (fishing mortality coefficient, yr^{-1})	0.75	0.77	0.75
E (exploitation rate)	0.51	0.50	0.50
S (total survival rate, yr^{-1})	0.23	0.22	0.22
1-S (total mortality rate, yr^{-1})	0.77	0.78	0.78
L_r (length at recruitment, cm)	15	15	15
L_c (length at first capture, cm)	20.0	21.0	20.5
K (growth coefficient, yr^{-1})	0.282	0.314	0.297
t_0 (age at which length is nil, yr)	-0.71	-0.62	-0.63
t_r (age at recruitment, cm)	0.85	0.83	0.84
t_c (age at first capture, cm)	1.57	1.66	1.60
L_∞ (asymptotic length, cm)	42.2	41.1	41.8
W_∞ (asymptotic weight, g)	1195	1257	1259

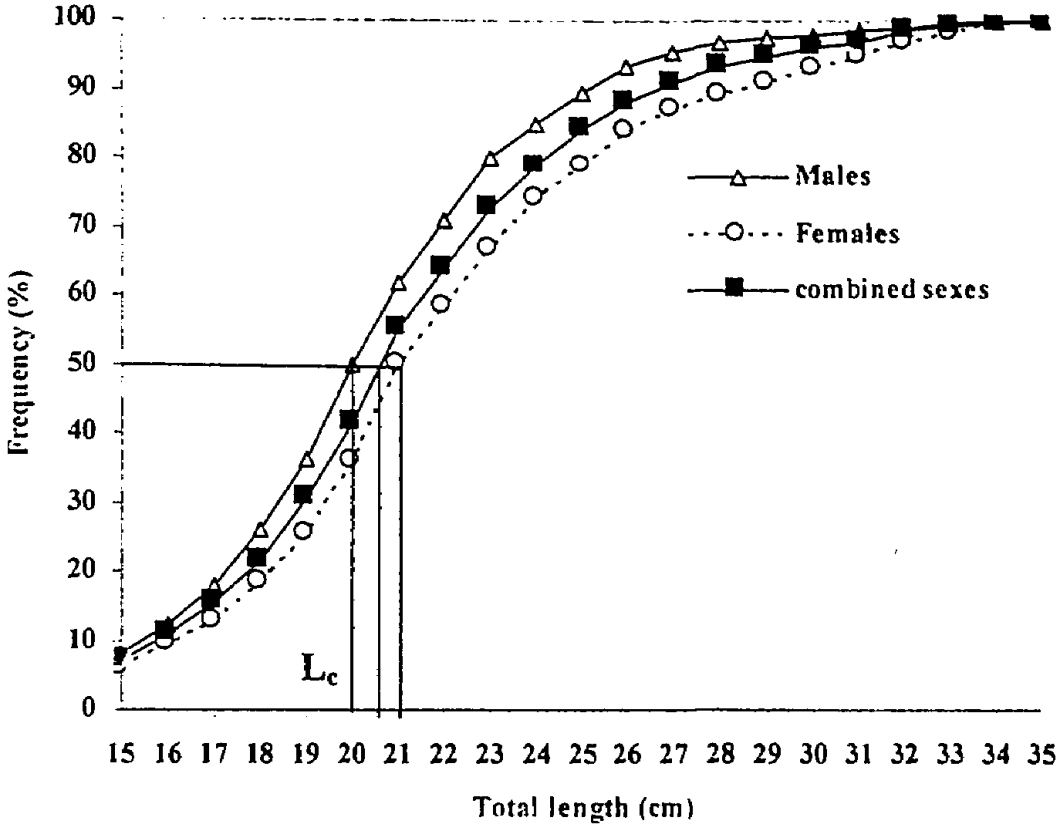

Fig. 1 Gear selection curves for males, females, and combined sexes of *Siganus canaliculatus* showing the length at first capture (L_c or $L_{50\%}$).

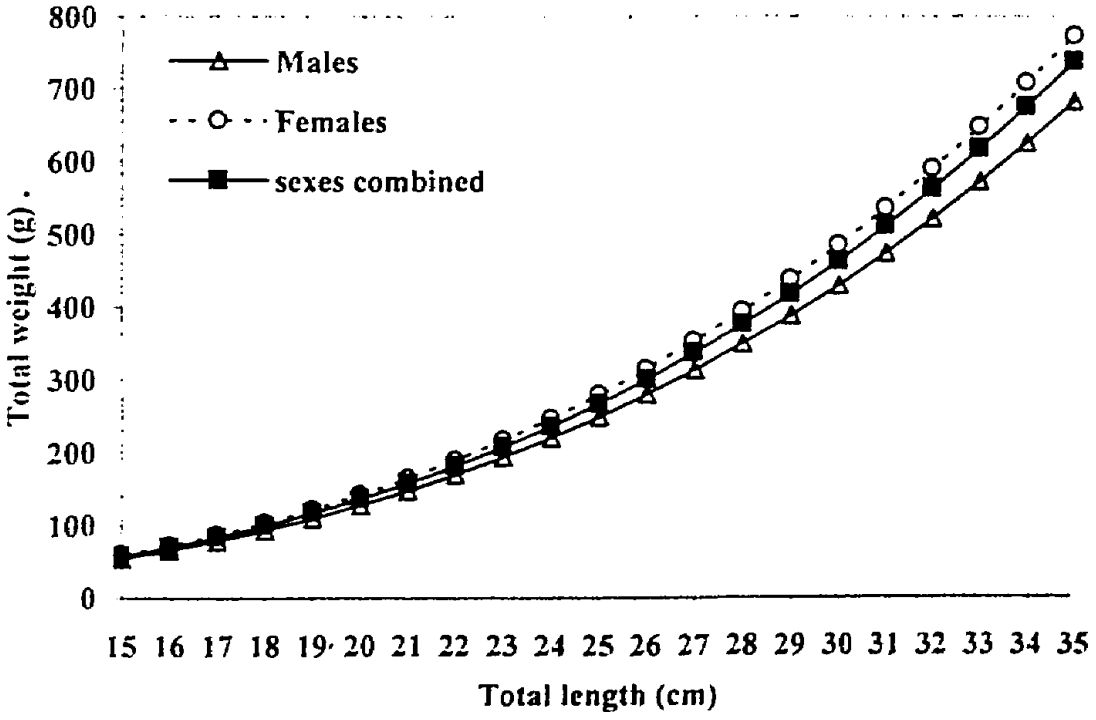

Fig. 2 Length-weight relationship for males, females, and combined sexes of *Siganus canaliculatus*

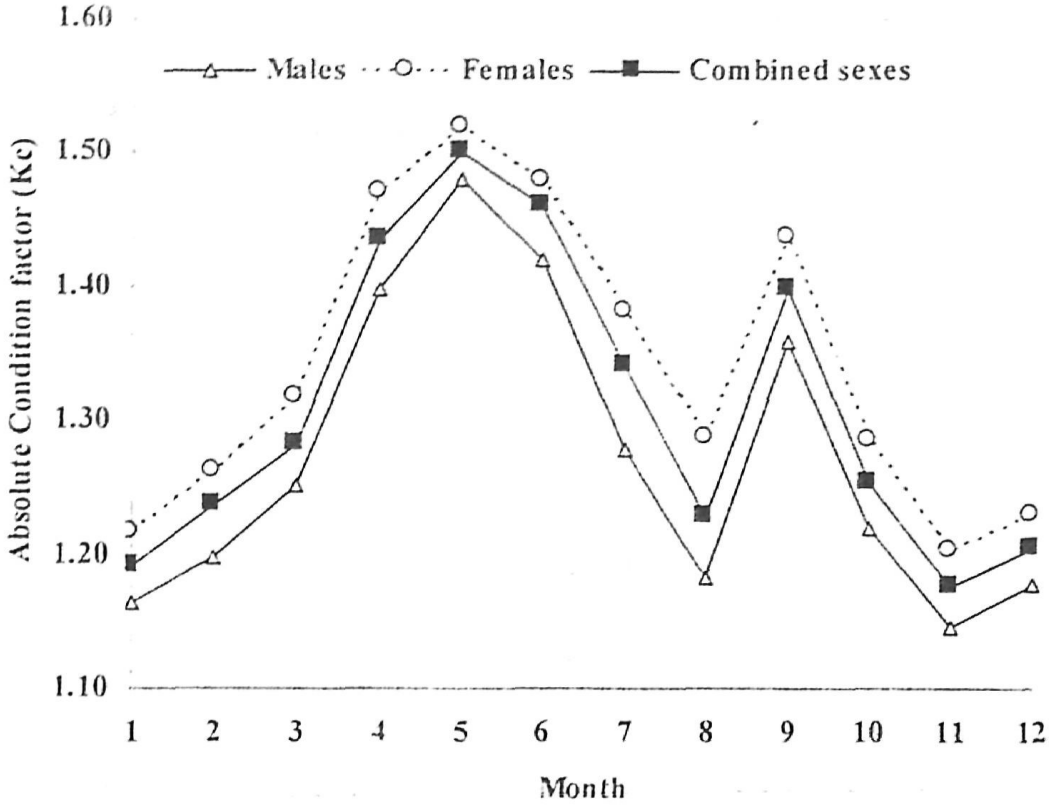

Fig. 3 Monthly absolute Condition factors (K_c) for males, females, and combined sexes of *Siganus canaliculatus*

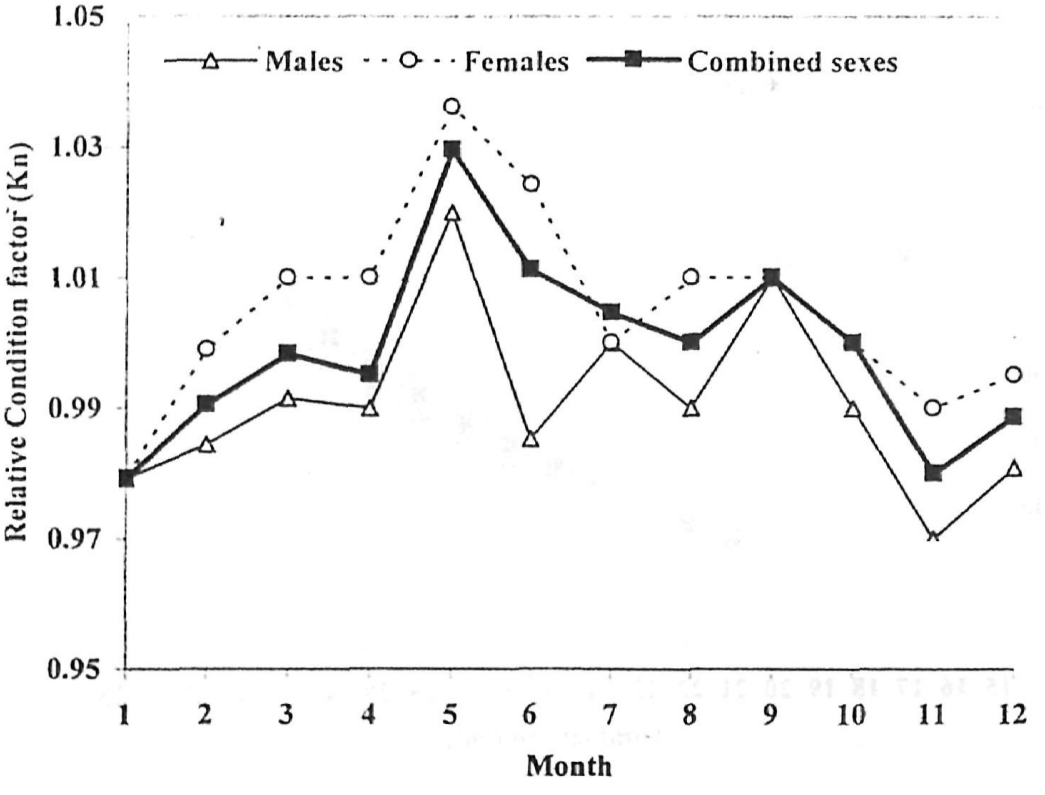

Fig. 4 Monthly relative Condition factors (K_n) for males, females, and combined sexes of *Siganus canaliculatus*

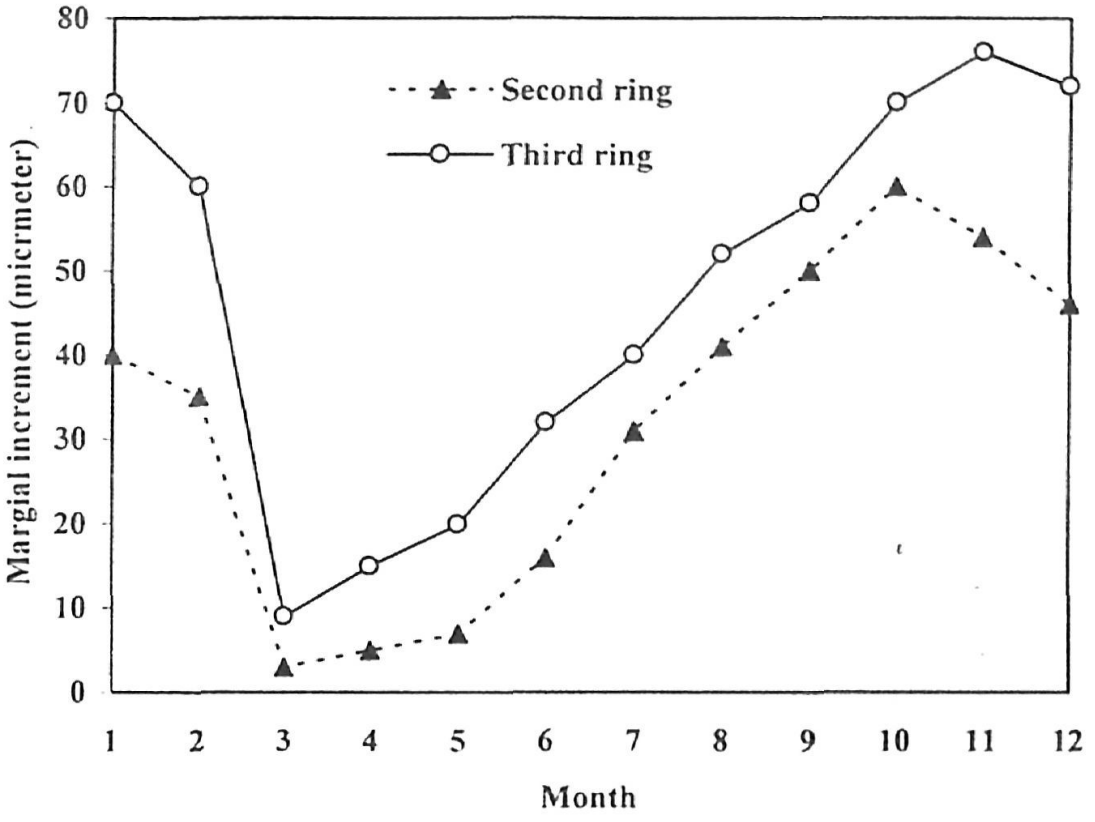

Fig. 5. Marginal vertebrae increments of second and third annual rings of combined sexes of *Siganus canaliculatus* plot by month.

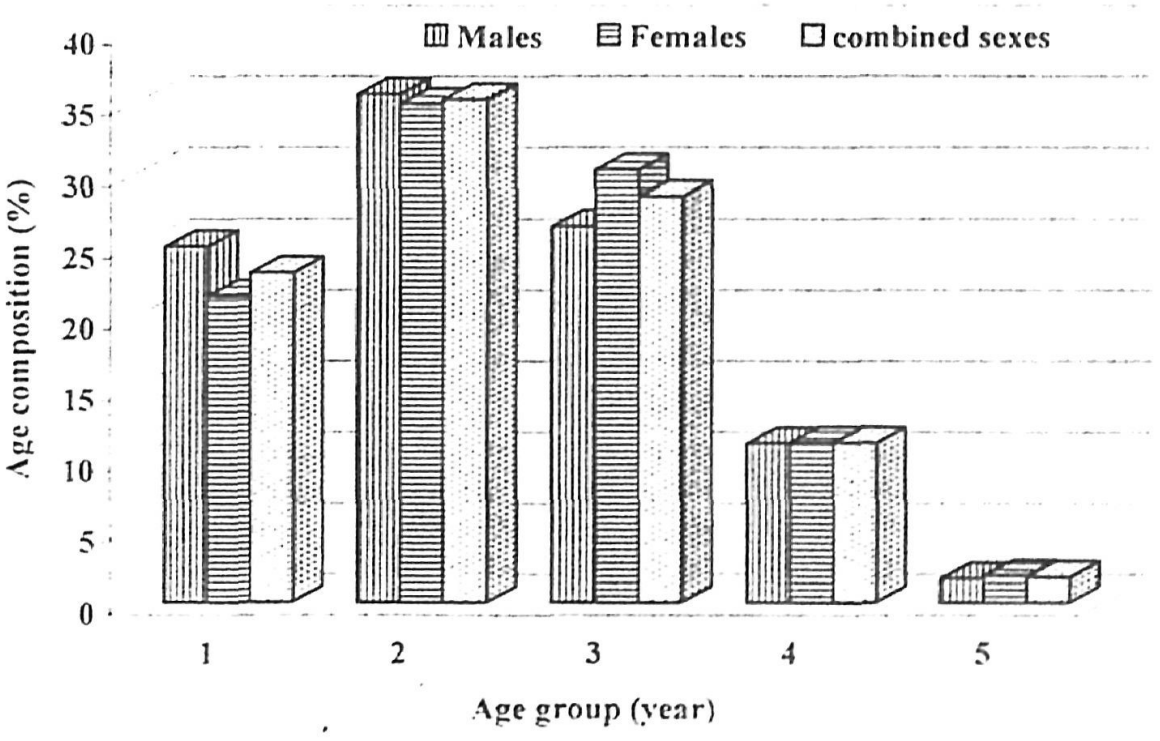

Fig. 6 Age composition for males, females, and combined sexes of *Siganus canaliculatus* from the Arabian Gulf at Saudi Arabia.

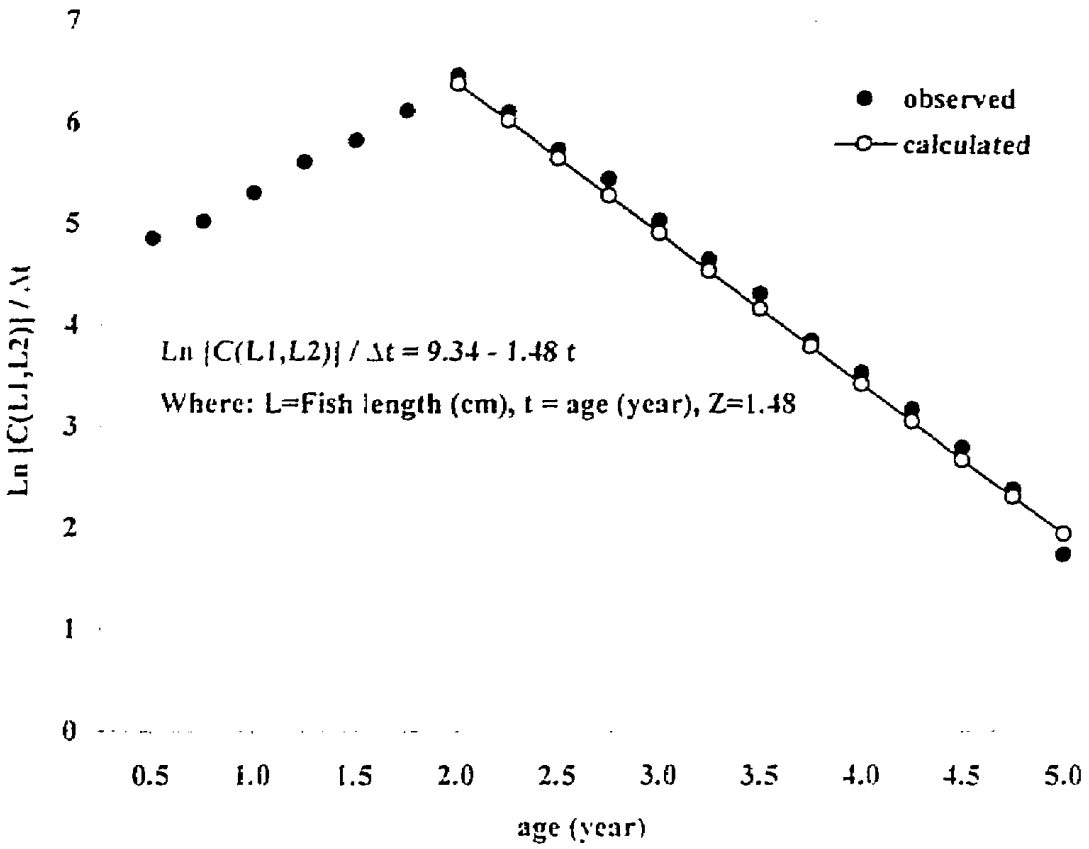

Fig. 7 The linearized catch curve based on length composition data to estimate total mortality (Z) for males of *Siganus canaliculatus*.

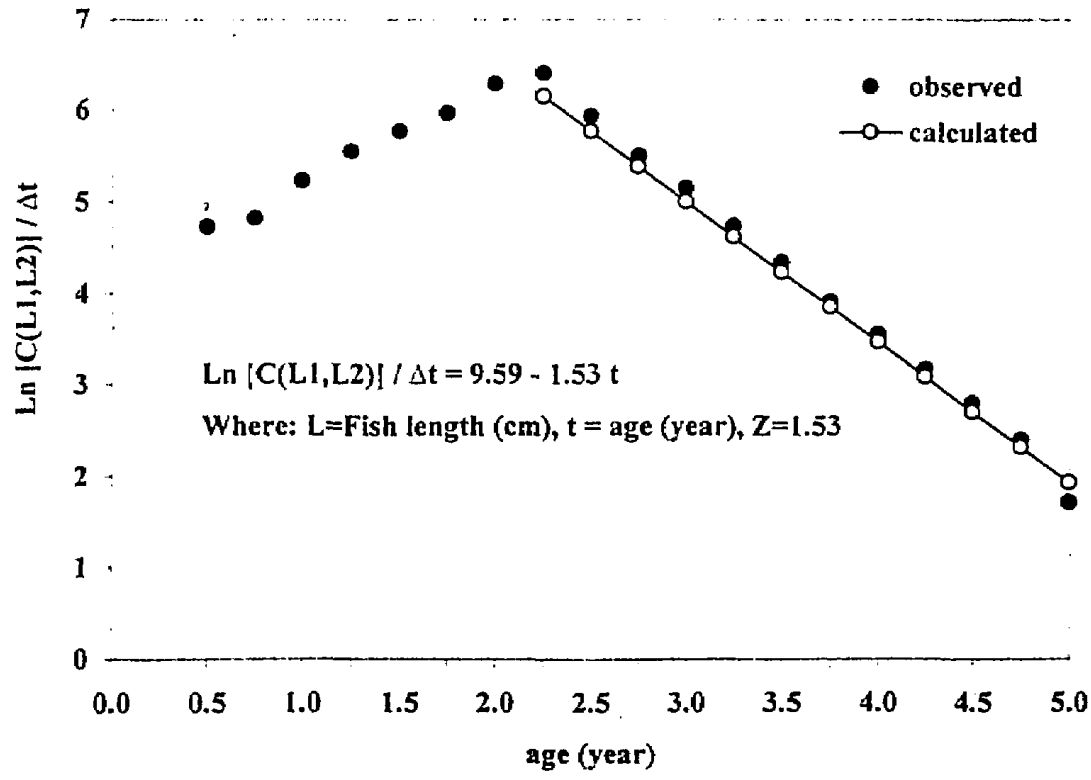

Fig. 8 The linearized catch curve based on length composition data to estimate total mortality (Z) for females of *Siganus canaliculatus*.

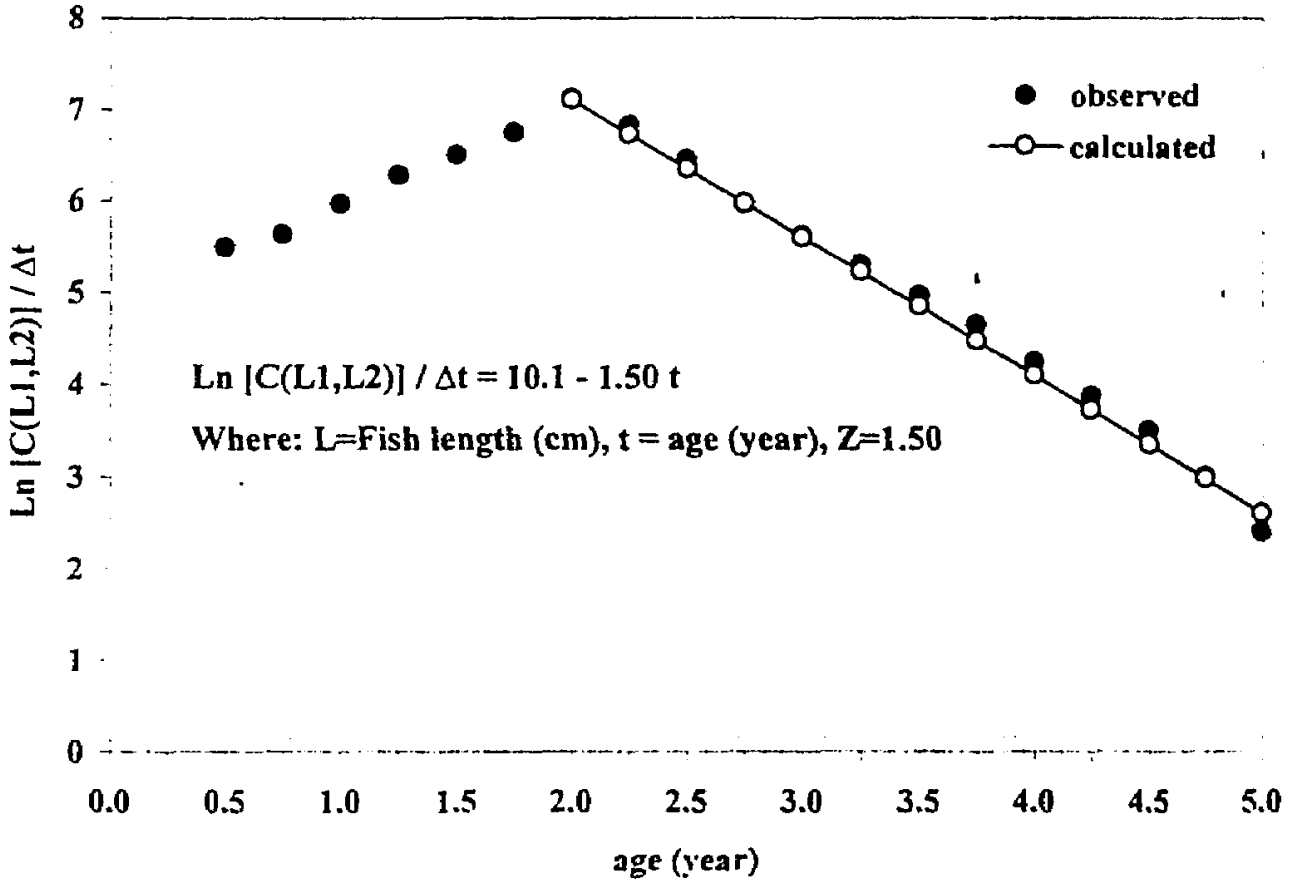

Fig. 9 The linearized catch curve based on length composition data to estimate total mortality (Z) for combined sexes of *Siganus canaliculatus*.