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Stock assessment of white spotted rabbitfish (*Siganus canaliculatus* Park, 1797) in Jubail marine wildlife sanctuary, Saudi Arabia

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Abstract
The aim of the study is to provide biological reference points on growth, mortality and other pertinent information on sustainable exploitations required for fisheries management. Length-frequency samples on a monthly basis were recorded from Al-Freya landing site at the Jubail marine wildlife sanctuary, east of Saudi Arabia during the period from April 2012 to January 2013. The FISAT II Program was applied to analyse the length frequency data. The growth results revealed that fish attained the lengths 11, 19, 24, 27 and 29 cm at the end of I, II, III, IV and V years, respectively. The growth parameters obtained were L_∞ = 35.38 cm and K= 0.583. The instantaneous rate of total mortality (Z), natural mortality (M) and fishing mortality (F) were 1.95 1.02 and 0.93 respectively, and the exploitation ratio (E) was 0.48 indicating a suitable level of current exploitation in Jubail fisheries. The length at first capture (L_c) was 17.24 cm, which is lower than the length at first maturity (L_m) reported in the Arabian Gulf. The virtual population analysis indicated that the fishing is concentrated mainly on length groups 16–24 cm. The results of yield per recruitment showed that the current exploitation rate of rabbitfish stock in Jubail is slightly lower than the optimum exploitation level. The maximum (Y'/R) could be achieved at length 23.5 cm, representing optimum L_c, which need to be considered as immediate management action to be adopted by Jubail Fisheries Directorate by increasing the current mesh size of drift nets used as part of regulation to maintain sustainable exploitation.

Keywords: Stock assessment, Rabbitfish, sustainable exploitation, Jubail, Saudi Arabia

1. Introduction

The white-spotted rabbit fish, *Siganus canaliculatus*, locally known "Safi" is a common herbivorous fish species of the family Siganidae, widely distributed in the Indo-Pacific region from the Arabian Gulf to the Indo-Malay region, Western Australia and north to Hong Kong and Taiwan [1] and also be found in the Eastern Mediterranean [2]. The *S. canaliculatus* is well distributed in coastal waters within depths less than 40 m [3].

Although, relative small size characterized *S. canaliculatus*, this species is considered as one of the marketable food fishes in the Arabian Gulf and Saudi Arabia as well. The most common fishing gear in Jubail fisheries is the shrimp trawlers constituting ~ 33%, followed by drift nets (23%), hook and line 22.6% and 21.4% for others, including barrier traps "locally known Hadrah" and dome-shaped wire traps "locally known Gargoor" [4]. The fish statistics in Jubail from 2003 to 2007 showed an increasing pattern in the catch of *S. canaliculatus* where the contribution raised from 3% (28 tones) to 10% (221 tones), however the catch rate dropped to less than 1% in 2011 [5].

Few accounts published on biological aspects of *S. canaliculatus*. The most significant contributions are carried out by Al-Ghais [6], El-Sayed and Bary [7], Wassef and Abdul Hady [8, 9] and Al-Marzouqi *et al*. [10]. However, due to rapid growth rate and marketable value, the interest in culturing rabbit fish in the Arabian Gulf has been widely directed.

Regarding the fisheries in Jubail, study undertaken by Esseen [11] concerned with fishing activity in Jubail marine wildlife sanctuary for a short period (March and May 1993). The study focused on the types of fishing gears, fishing vessels and common marine species that are caught. Al-Emad [12] pointed out the stresses on Jubail marine wildlife sanctuary affecting the marine living resources. The study carried out by Tharwat [13] on the fishery assessment seems to be the only

reference dealing with *S. canaliculatus* in the Saudi Arabia coasts on the Arabian Gulf. Similar studies were conducted in UAE by Grandcourt *et al*. [14] and in Qatar by Abdallah *et al*. [15].

The assessment of fish stock is of growing importance for fisheries management to set strategically plan considering food security challenges under high rate population growth and increasing trend of fish demand. The aim of the present study is to assess the stock of *S. canaliculatus* in the study area, as part of commercial catch, through providing biological reference points (growth, mortality and recruitment) and other pertinent information on sustainable exploitations required for fisheries management.

2. Materials and Methods

The monthly length-frequency samples analysed in the present study were drawn from the fish landing site at Jubail marine wildlife sanctuary (Fig. 1). Specimens of *S. canaliculatus* in the size range of 8 to 34 cm were collected randomly from the commercial catches landed in Al-Freya site at Jubail marine wildlife sanctuary. The sampling period lasted from April 2012 to January 2013. Total lengths (snout to caudal fin tip) of individuals were recorded to the nearest 0.1 cm. The growth, mortality, recruitment and exploitation rates were obtained using the routines in FISAT program (FAO ICLARM Stock Assessment Tools) version II software package [16].

The growth parameters (asymptotic length L_∞ and growth coefficient K) were derived using Munro's method routine. The Phi-prime index, φ [17], was used to compare the growth performance of species studied with previous estimates for the same species in adjacent waters. A selectivity curve was generated using linear regression fitted to the ascending data points from a plot of the probability of capture against length, which was used to derive the length at first capture (L_{50} or L_c) and values of the lengths at capture at probabilities of 0.25 (L_{25}), 0.75 (L_{75}) and 1 (L_{100}) as well.

Total mortality (Z) was estimated by length converted catch curve [18]. Natural mortality (M) was calculated following the empirical equation of Pauly [19]; mean annual habitat temperature used was 22 °C, which is assumed to reflect the annual mean of surface water's temperature. The annual instantaneous rate of fishing mortality (F) was obtained by subtracting the natural mortality rate (M) from the total mortality rate (Z) according to Beverton and Holt [20]. The exploitation rate was estimated by the Beverton and Holt's formula [21], as the proportion of the fishing mortality relative to total mortality, E = F/Z. The relative yield-per-recruit (Y'/R) was estimated using the knife-edge method of Beverton and Holt's model [21], by which the maximum exploitation rate (E_{max}) and optimum exploitation rate (E_{otp}) were obtained.

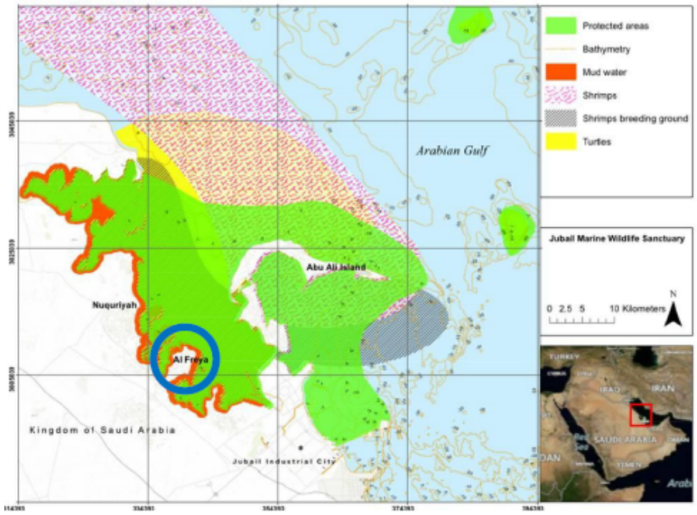

Fig 1: Location map of Jubail area, Saudi Arabia showing Al-Freya fish landing site

3. Results

3.1 Length composition

The total lengths of *S. canaliculatus* collected during the study period were ranged from 8 cm to 34 cm. As overall, the dominant length groups was ranged between 18 cm and 20 cm (Fig. 2) constituting approximately 35%.

3.2 Growth

The estimates of the growth parameters L_∞ and K obtained were 35.38 cm and 0.583 per year (Fig. 3). The growth curve showed that *S. canaliculatus* operate upon 5 cohorts of the population. Following to von Bertalaanffy growth equation, the *S. canaliculatus* attained the lengths 11, 19, 24, 27 and 29 cm at the end of I, II, III, IV and V years, respectively. The mean of lengths at different age groups indicated rapid growth in the 1st year of life with fish attaining almost 35 % of its maximum size, whereas in the following years the rate of growth slows down.

The growth performance index (φ) obtained according to growth parameters was 2.86.

The mean length at first capture (L_c or L_{50}) was 17.24 cm (TL) and the lengths at capture at probabilities of 0.25 (L_{25}), and 0.75 (L_{75}) were estimated to be 16.12 cm, 18.34 cm, respectively (Fig. 4). Fish were fully recruited to the fishery (L_{100}) at a size of 21.7 cm.

3.3 Mortality

The annual instantaneous rate of total mortality (Z) estimated from the length converted catch curve was 1.95 (Fig. 5). The solid line shows the regression equation fitted to data for length converted catch curve. The lengths for small ages (yellow circles) showing ascending line were excluded as

those not represent fully exploited groups. The last two length groups were also excluded due to insufficient number of individuals represented.

The annual instantaneous rate of natural mortality (M) derived from the Pauly's empirical formula was 1.02. The average water temperature for the study period that was used was 22 °C. The calculated annual instantaneous rate of fishing mortality (F) was 0.93. The current exploitation (E) was estimated as 0.48 indicating suitable level of current exploitation.

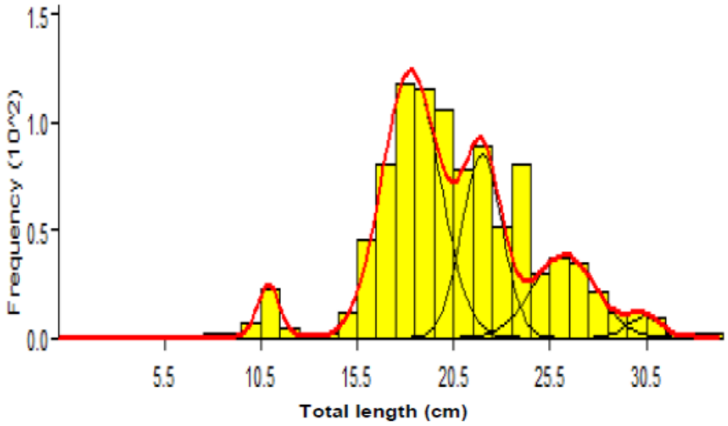

Fig 2: Length frequency distribution of *S. canaliculatus*

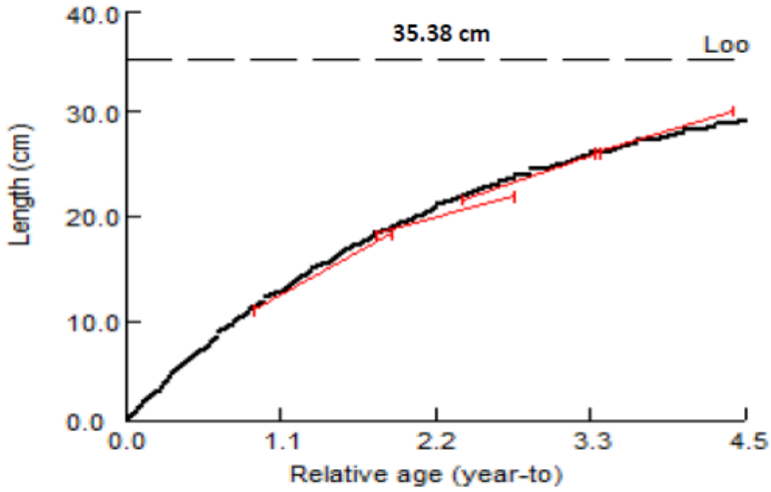

Fig 3: Growth curve of *S. canaliculatus* by Munro plot

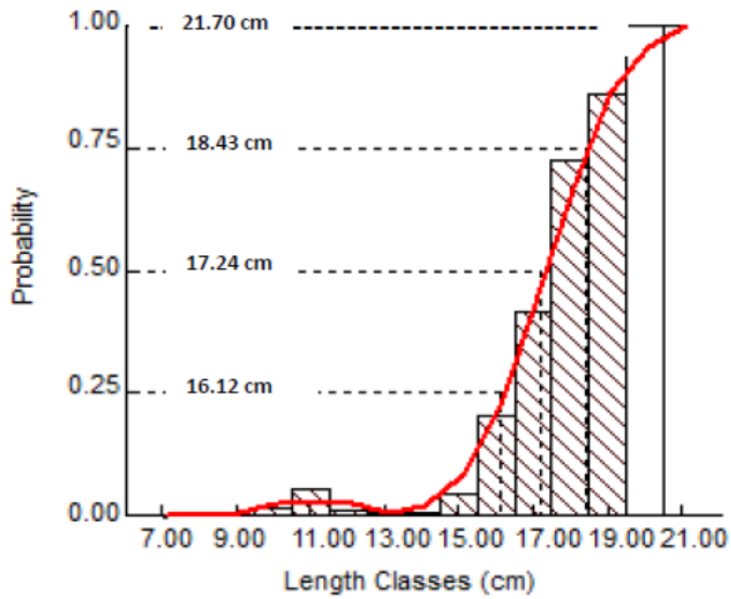

Fig 4: Selectivity catch curve showing probability captures of *S. canaliculatus*

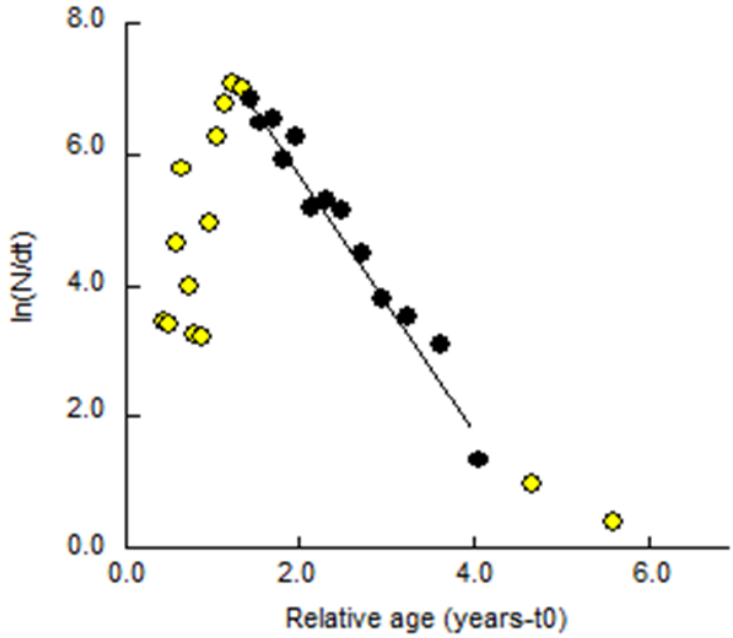

Fig 5: Length converted catch curve of *S. canaliculatus*

3.4 Virtual Population Analysis VPA

Virtual population analysis indicated that main loss in the stock up to 15 cm size was due to natural causes (Fig. 6). Fishes became more vulnerable to the gear after this size and mortality due to fishing increased and eventually outnumbered the natural losses from 16 cm onwards. The maximum fishing mortality of 1.2 was recorded at length of 24 cm.

3.5 Yield per Recruit

The relative yield-per-recruit (Y'/R) was determined as a function of L_c / L_∞ and M / K (Fig. 7). The current exploitation (E) of population obtained in the present study was lower than the maximum allowable limit (yellow broken line) based on yield-per-recruit calculation (E_{max} = 0.649), which leads to the maximum sustainable yield (MSY), and at the same time the current exploitation was lower than the optimum exploitation rate (E_{opt} = 0.566), which represented by green broken line. Several values of length at first capture (L_c) ranging from 14 cm to 30 cm were run against current, optimum and maximum exploitation rates to find out the length at which maximum relative per recruit (Y'/R) could be obtained. The results revealed that the (Y'/R) gradually increased within L_c increase up to the length 23.5 cm (Fig. 8), at which the maximum (Y'/R) could be achieved where the level attains 0.067, 0.079 and 0.0978 for current, optimum and maximum exploitation rates respectively. However, the levels dropped down with any further increase in Lc beyond 23.5 cm indicating that this length is the optimum length at first capture to maintain the sustainable exploitation of *S. canaliculatus* in Arabian Gulf Saudi Arabia coast.

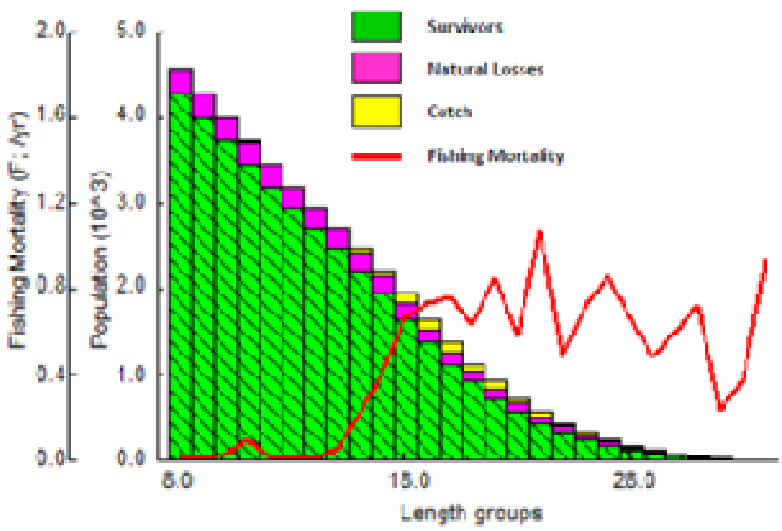

Fig 6: Length structured Virtual Population Analysis for *S. canaliculatus*

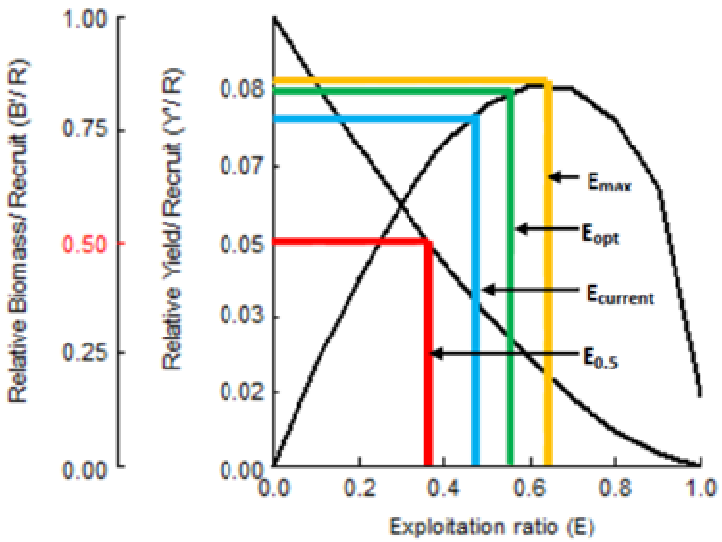

Fig 7: Relative yield per recruit (Y'/R) curve of *S. canaliculatus* showing optimum and maximum exploitation rates

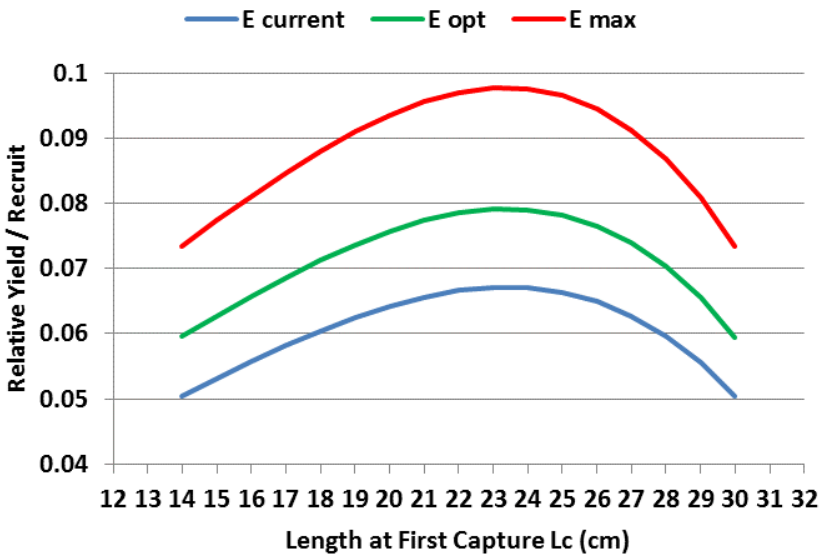

Fig 8: Relative per recruit (Y'/R) of current, optimum and maximum exploitation rates based on different L_c values of *S. canaliculatus*

4. Discussion

The present study is based is on the utility of length frequency as a function for length-based approaches to assess the white spotted rabbit fish stock at the Jubail marine wildlife sanctuary. The use of length-based method is spreading widely and successfully adopted particularly in tropical and subtropical regions providing set of options for fish stock assessment.

The value of growth performance index φ, merging the L_∞ and K, obtained in the present study is more or less within the range obtained in other Arabian Gulf localities; however, it seems lower than those obtained Philippines and Paula as indicated in Table (1). The spatial variations in these values could be attributed to ambient environment, physiological conditions, food availability, fishing pressure and analytical methods as well.

Beverton and Holt [20] pointed out that the natural mortality coefficient is directly related to the growth coefficient (K) and inversely related to the asymptotic length (L_∞) and the life span longevity. Accordingly *S. canaliculatus*, which characterized by moderate growth rate of 0.583 per year and relatively shorter lifespan of 5 years was found to have considerable fraction of natural mortality coefficient (M) as 1.02 per year. The M/K ratio obtained in the present study (1.75) was well within the normal range of 1 – 2.5, as suggested by Beverton and Holt [25]. As a rule the Z/K ratio of 1.0 is considered as growth dominated and if it is more than 2, then it is mortality dominated. In the present study, it was equal 3.34, which showed that the fishery of *S. canaliculatus* was mortality dominated.

The results summarized in Table (2) indicated that the lengths at first capture (L_c) of *S. canaliculatus* in the Arabian Gulf fisheries are lower than the lengths at first maturation (L_m), which confirmed that the majority of the stock tend to mortality dominated trend due to removal of pre spawning fishes.

Gulland [26] suggested that in an optimally exploited stock, fishing mortality should be about equal to natural mortality, resulting in an exploitation rate of 0.5. The present results suggest that the population of *S. canaliculatus* is being exploited close to the optimum exploitation level. These findings confirmed by the yield per recruitment results, where the current exploitation rate is lower than both the optimum exploitation rate (E_{opt}) and the maximum allowable limit

(E_{max}). These findings imply that the exploitation of the fish stock is lower than the maximum fishing level and thereby the present fishing mortality is still marginally around the optimum fishing effort exerted, i.e., management measures required to keep at such level. With the exception of Qatari waters, the exploitation rates listed in Table (2) referred to suitable levels, which seem to be more or less close to optimum exploitation rate (0.50).

To maintain the sustainable fishery exploitation it is of great importance to give an opportunity for fish to reproduce at least once during its lifespan to recruit the stock. This could be achieved when the length at first capture (L_c) being bigger than the length at first maturation (L_m). In the present study as illustrated in (Fig. 9) the length at first capture (L_c = 17.24 cm) is attained before the 2nd age group. The length of fully recruited to the fishery (L_{100} = 21.7 cm) and the length at first maturation (L_m) is attained after the 2nd age group at lengths 19 and 21.5 cm as reported by Tharwat [27] and Grandcourt *et al.* [14] respectively. As a result the current L_c is smaller than both (L_{100}) and (L_m). Moreover, the length group 24 cm, representing fishes older than 3rd age group, are the lengths under full exploitation contributing the majority of the maximum fishing mortality.

These findings asserted the results derived from the test based on several L_c values given to attain maximum (Y'R), which indicated that the mid length 23.5 cm is the optimum L_c to be adopted. Consequently, immediate management action, regarding regulations on drift fishing nets used need to be considered by Jubail Fisheries Directorate on increasing mesh size to avoid removal of pre-spawner fishes by which sustainable exploitation to be maintained.

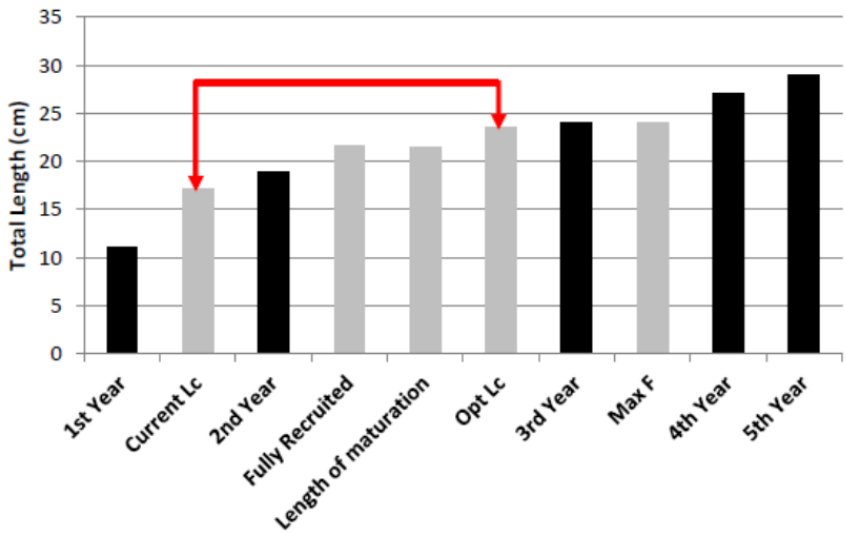

Fig 9: Age groups and lengths related to first capture (L_c), maturation (L_m), fully recruited and maximum fishing of *S. canaliculatus*

Table 1: Comparison of growth performance index (φ) of *S. canaliculatus* from different regions

Region	GPI (φ)	Reference
Philippines	3.08	Pauly [22]
Paula	3.19	Kitalong and Dalzell [23]
Malaysia	2.5	Ahmed *et al.* [24]
Arabian Gulf, Saudi Arabia coast	2.72 (Females) 2.69 (Males)	Tharwat [13]
Southern Arabian Gulf	2.77 (Females) 2.82 (Males)	Grandcourt *et al.* [14]
Qatar	3.11	Abdallah *et al.* [15]
Jubail, Saudi Arabia	2.86	Present study

Table 2: Summary on stock assessment outputs of *S. canaliculatus* from adjacent waters in the Arabian Gulf

Region	L_c (cm)	L_m (cm)	L_{100}	Z	M	F	E	Reference
Saudi Arabia, Eastern coast	-	19	-	1.50	0.75	0.75	0.50	Tharwat [13]
UAE	15*	21.7*	19.7*	1.51	0.66	0.85	0.56	Grandcourt *et al.* [14]
Qatar	22.44	-	-	3.61	1.15	2.46	0.68	Abdallah *et al.* [15]
Saudi Arabia, Jubail	17.24	-	21.7	1.95	1.02	0.93	0.48	Present study

5. Conclusions

Although the current exploitation rate of the white spotted rabbitfish, *S. canaliculatus* stock in Jubail fisheries is slightly lower than the optimum exploitation level, the current length at first capture L_c (17.24 cm) is lower than the length at first maturity L_m (19 cm). To avoid removal of pre-spawner fishes, the current L_c need to be increased up to 23.5 cm. This will substantially support the sustainable exploitation of the white spotted rabbitfish stock in Jubail fisheries.

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