Growth, mortality and yield per recruit of the king soldier bream *Argyrops spinifer* (Sparidae) from the Oman coast of the Arabian Sea

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Abstract

The King soldier bream *Argyrops spinifer* at Arabian Sea (Omani waters) was assessed using Beverton and Holt yield per recruit model. A total of 5520 specimens were collected during five trawl surveys between September 2007 and August 2008. The maximum life span was 11 years for length range of 11.0 – 62.1 cm TL. The von Bertalanffy growth parameters were K = 0.22 $year^{-1}$, L_∞ = 65.51 cm, t_o = -0.75 year and W_∞ = 5430g. The rates of total mortality Z, natural mortality M and fishing mortality F were 0.85, 0.26 and 0.59 $year^{-1}$ respectively. The exploitation ratio E was 0.69 indicating the high level of exploitation. The estimated total length at 50% maturity was 31.8 cm. Yield per recruit analysis revealed over-fished stock conditions particularly because small fish are effectively unprotected by current minimum size regulations. Therefore measures such as closed seasons or changes in fishing patterns would be desirable to safeguard the spawning stock and recruits. Also, the commercial fishery of Arabian Sea, Oman should be subjected to a total allowable catch and a maximum size limit be implemented.

Keywords: Arabian Sea, *Argyrops spinifer,* age validation, per-recruit analysis, fisheries regulations

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Introduction

Seabreams (Family Sparidae) are a predominantly marine family, which is found in the Indian, Pacific and Atlantic oceans (Nelson, 1994) and contains many species of commercial and/or recreational importance and some that are used for aquaculture (Foscarini, 1988; Cetini et al., 2002; Ingram et al., 2002).

Seabreams are an important component in Oman demersal fisheries. They exploited by different types of fishing gears yielding a mean of 8000 tonnes annually achieving about 11 million Omani Riyals (OR ≈ 2.6$). Seabreams were found all along the Oman coast of the Arabian Sea, with highest densities from Ras Al Hadd to Masirah Island (Fig. 1) at depths ranged between 10 and 90 m but the majority were concentrated in the shallowest waters at depths 20-50 m.

One of these important species is the king soldier bream *A. spinifer* (Forsskål, 1775). The king soldier bream is distributed throughout the Western Indian Ocean extending eastward to the Indo-Malayan archipelago and northern Australia. While it inhabits a wide range of bottom types to 100 m depth, young individuals occur in very shallow waters of sheltered bays (Sommer et al., 1996). Although the commercial importance of this species, a few studies on its biology and fisheries are available (Druzhinin, 1975 in Yemen; Edwards et al., 1985 in Yemen; El-Sayed and Abdel-Bary, 1995 in Qatari waters, Grandcourt et al., 2004 in the Persian Gulf, UAE; Al-Mamry et al., 2009 in Omani waters; Raeisi et al., 2011 in the Persian Gulf, Iran). So, the present work is directed to provide a preliminary assessment of *A. spinifer* from the Arabian Sea coast of Oman. This may help to suggest the required fisheries regulations to sustain and manage this fish resource.

Figure 1: Map of study area in the western Arabian Sea

Materials and methods

A total of 5520 specimens of *A. spinifer* (11.0 – 62.1cm TL) were collected from the Oman coast of the Arabian Sea from September 2007 to August 2008 during five demersal surveys (Fish Resources Assessment Survey of the Arabian Sea Coast of Oman Project). Each fish was measured to the nearest mm for total length TL and weighed to the nearest 0.1 g total weight, and then sex and maturity were determined macroscopically. Otoliths were taken for each specimen, cleaned and stored dry for later age determination. Annual rings (each alternating translucent and opaque zones together) on whole otolith were identified and counted using optical system consisting of Zeiss research microscope at 4× and 10× magnifications connected to AxioCam HRC and Ziess KL 1500 LCD using transmitted light. The total radius of otolith and the radius of each annulus were measured to the nearest µm. Regression analyses of otolith maximum radius - total length was calculated by the method of least squares. Back-calculated lengths-at-age were computed by using the Lee method (Lagler, 1956).

The left otolith was embedded in clear epoxy resin and sectioned using a Buehler Isomet low-speed saw containing a diamond wafering blade which cuts a thin section (300µm) through the nucleus. A grinding wheel fitted with silicon carbide paper with different grit sizes (400 to 1200 grit) flushed with water was used to remove excess resin on the face of the sections and to provide a polished face for viewing. The section is then mounted on a glass slide and read under a Zeiss compound microscope equipped with zoom lens and (magnification up to 60×) using transmitted light.

Whole and sectioned otoliths were read independently twice with no reference to the previous readings and without any knowledge of the length or weight of the fish. The precision was measured by the percentage of agreement between the two readings (Lowerre-Barbieri et al., 1994). Only counts with agreements were used in subsequent analysis. Reproducibility of the resultant age estimation was evaluated with the coefficient of variation (CV) (Chang, 1982) and the index of average percent error (IAPE) (Beamish and Fournier, 1981).

To estimate the relation between total length (L) and total weight (W), the variables were log-transformed to meet the assumptions of normality and homogeneous variance. A linear version of the power function: $W = aL^b$ was fitted to the data. Confidence intervals (CI) were calculated for the slope to see if it was statistically different from 3.

Growth curves, based on biological ages were constructed using the Von Bertalanffy growth function as: $L_t = L_\infty (1- e^{-k (t - to)})$ where L_t = length at time t, L_∞ = asymptotic length, k = growth coefficient, t = time, and t_o = age at time zero. Back-calculated lengths of pooled data were applied according to Ford (1933)-

Walford (1946) plot to estimate the von Bertalanffy growth parameters.

The instantaneous coefficient of total mortality Z was estimated using Beverton and Holt's (1956) equation as $Z = K*(L_\infty - \acute{L})/(L_\infty - L')$, where $\acute{L}$ is the mean length of fish of length L' and longer, while L' is the lower limit of the length class of highest frequency.

The instantaneous coefficient of natural mortality M was estimated as the geometric mean of three methods (Taylor, 1960; Ursin, 1967; Rikhter and Efanov, 1976), while the instantaneous coefficient of fishing mortality F = Z–M and the exploitation ratio E was estimated as E = F/Z (Gulland, 1971).

The mid-point of the smallest length group in the catch during the survey period was taken as the length at recruitment (L_r), while the length corresponding to the first value in the descending limb of the length converted catch curve was taken as the length at first capture (L_c) (Pauly, 1987). Both L_r and L_c were transferred to ages using the von Bertalanffy growth equation.

The length at first sexual maturity L_{50} (the length at which 50% of fish reach their sexual maturity) was estimated by fitting a logistic function to the proportion of the mature individuals by size class using a non-linear regression of the following function:

$$P = 1/\{1 + \exp[-r (L - L_m)]\}$$

Where: P is the proportion of mature specimens in each size class, r (- slope) is a parameter controlling the shape of the curve and L_m is the size at 50% maturity. The L_m = a/r where 'a' is the intercept.

The yield per recruit (Y/R) analysis was performed using the model of Beverton and Holt (1957) using the formula suggested by Gulland (1969) as follows:

$$Y/R = F\ e^{-K\ (Tc-Tr)}\ W_\infty\ [(1/Z) - (3S/Z+K) + (3S^2/Z+2K) - (S^3/Z+3K)]$$

Where: $S = e^{-K\ (Tc\ -\ to)}$, K is the the Von Bertalanffy growth parameter, T^c is the age at first capture, T^r is the age at recruitment, t^o is the age at which the length is nil, W_∞ is the asymptotic weight, F is the fishing mortality rate, M is the natural mortality coefficient and Z is the total mortality coefficient.

Results

To validate age determination of *A. spinifer* from the Arabian Sea, Oman, ages were determined by comparing the growth increment readings on sagittal otoliths (Fig. 2) and their sections (Fig. 3). It was found that the number of annuli counted for each individual was similar for the two readings and there was a high congruence (94.5%) between the age estimations from the two methods. Of the 398 otoliths and sections examined, consensus reached 372 (93.5%). The index of average percent error (IAPE) of band counts for each reading did not differ greatly. Precision of repeated age estimation was high, whole otolith readings were 92% in agreement with sectioned otoliths readings. The values of the IAPE and the CV suggested that the precision levels obtained are according to the reference point values indicated by Campana (2001).

The results revealed that the maximum observed ages for *A. spinifer* in the Arabian Sea was 11 years and age groups 1 and 2 were the most frequent groups in the catch and constituted 28 and 25%, respectively while the age group 11 was the least age group and formed 1.5% of the catch.

Mean lengths at age were back-calculated for *A. spinifer* using the resultant equation from total length- otolith radius relationship (Fig. 4). It was found that, the greatest incremental growth in TL occurred during the first year and then declined rapidly thereafter (Fig. 5).

Figure 2: Otolith of *Argyrops spinifer* (4 and 5 years old)

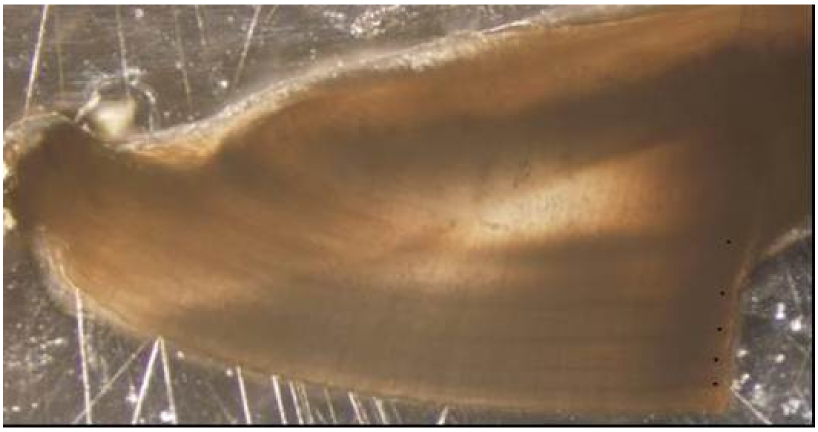

Figure 3: Sectioned otolith of *Argyrops spinifer* showing 5 annuli

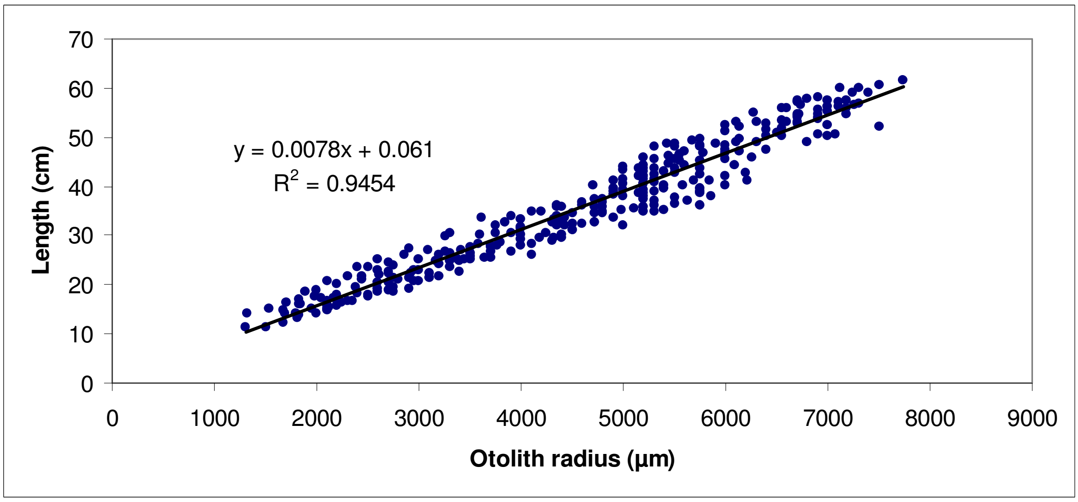

Figure 4: Total length- otolith radius relationship for *Argyrops spinifer* from the Arabian Sea

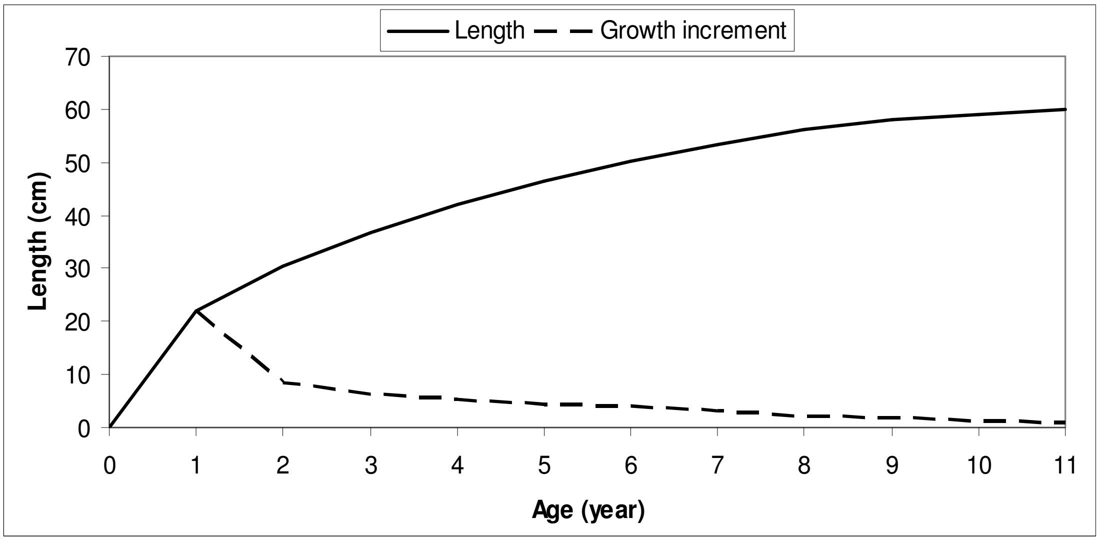

Figure 5: Length by age and growth increment for *Argyrops spinifer* from the Arabian Sea

The total length varied from 11.0 to 62.1cm, while the total weight ranged between 111 and 5380g. and the resultant equation (Fig. 6) was: $W = 0.040\ L^{2.8275}$ ($R^2 = 0.99$).

The calculated weights by age groups proved that the growth rate in weight was much slower during the first year of life increasing to reach its maximum at the end of the fourth year of life, then decreasing with further increasing in age (Fig. 7).

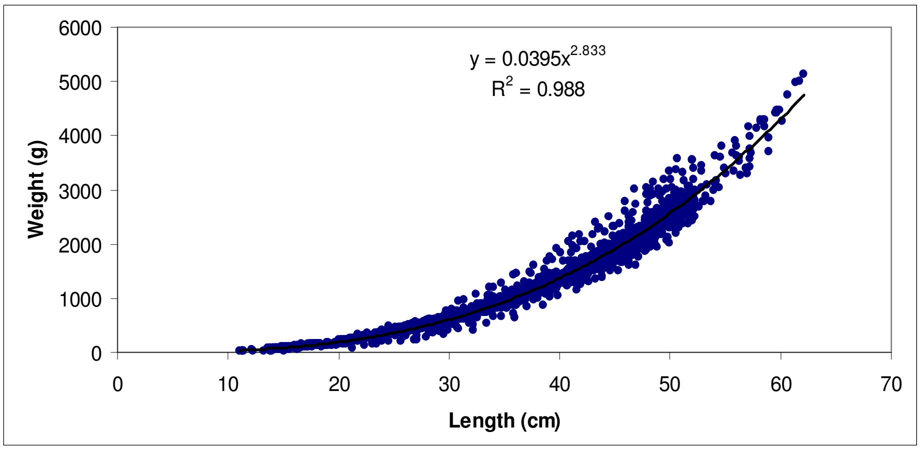

Figure 6: Length- Weight relationship for *A.spinifer* from the Arabian Sea

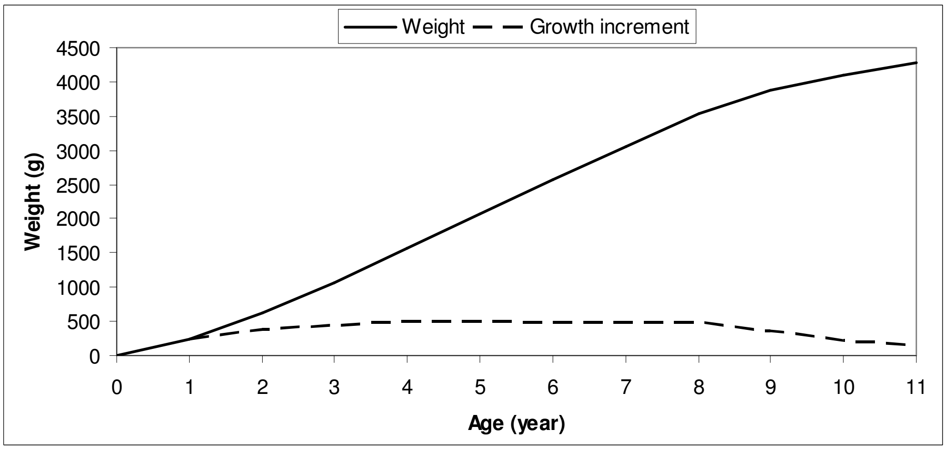

Figure 7: Weight by age and growth increment for *A. spinifer* from the Arabian Sea

The obtained values of von Bertalanffy growth parameters ($L_{\infty,}$ W∞ and K) were K = 0.22, L∞ = 65.51cm TL, t_o = -0.75 year and W∞ = 5430g.

The total mortality coefficient Z was estimated as 0.85 $year^{-1}$. The mean natural mortality coefficient M was 0.26 $year^{-1}$, while the fishing mortality coefficient F was 0.59 $year^{-1}$. Exploitation rate E was computed as 0.69.

The smallest length recorded in the catch was 11cm which considered as the length at recruitment, while the length at first capture was estimated as 25.9cm.

The smallest length recorded in the catch was 11cm and all fishes of lengths from 11 to 19cm were immature and those of lengths ≥ 44cm were mature. The estimated L_{50} was 31.8cm (Fig. 8).

The plot of yield per recruit Y/R and biomass-per-recruit (B/R) against Fishing mortality rate F gives a maximum (Y/R) at F= 0.35 so the current F should be reduced to this level (about 41%). At the present level of exploitation, and when we raised the age at first capture to 3 years (≈T_m), the yield per recruit increased by about 34% (Fig. 9).

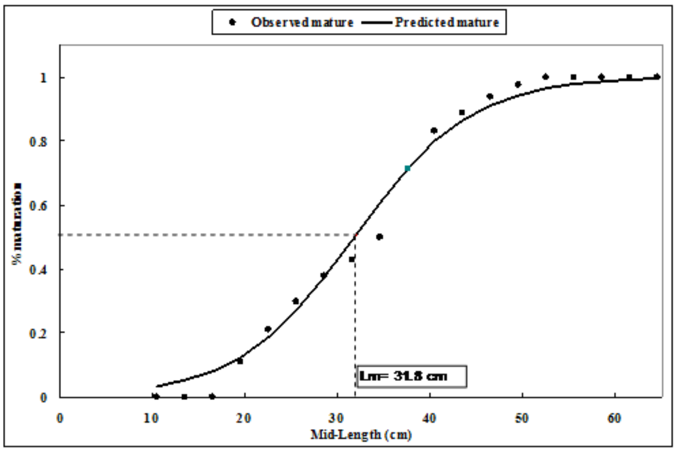

Figure 8: Length at first maturity for *A. spinifer* from the Arabian Sea

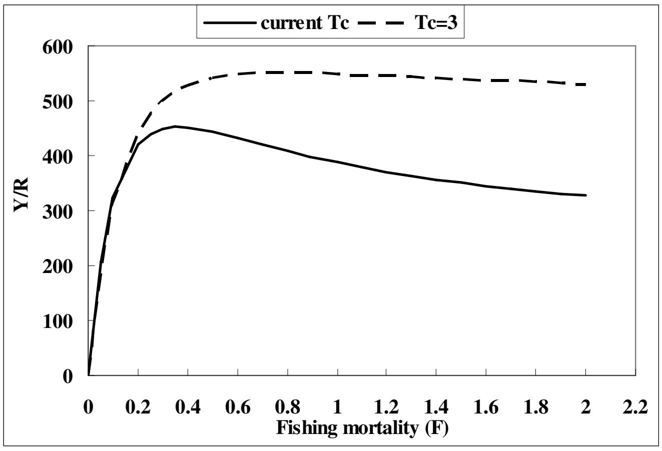

Figure 9: Yield per recruit model for *Argyrops spinifer* from the Arabian Sea

Discussion

This study has investigated the biological characteristics and population parameters of one of the most important sparid species in the Arabian Sea coasts of Oman; *A. spinifer* as well as it provided the required information for its rational exploitation.

One of the most serious mistakes made by fisheries biologists is the failure to validate the age determination procedure that provides accurate age confirmation of the ageing technique. Without exception, age determination techniques must be validated for all age classes in the population and each time they are applied to a new species. In the present study, the age determination of *A. spinifer* was validated by comparing the annuli readings between the whole and sectioned otoliths. The values of the IAPE and the CV suggested that the precision levels obtained are according to the reference point values indicated by Campana (2001).

The maximum life span recorded in the present study (11 years old) was differ from that reported in the only previous work dealing with age determination of this species in the Arabian Sea (Al-Mamry et al., 2009). They found that, female and male *A. spinifer* age ranged between 2 and 25 years for total length ranged from 20 to 68 cm for males and from 25 to 70 cm for females. The age overestimation in their study may be due to considering the false rings during their counting the annuli on the otolith. On the other hand El-Sayed and Abdel-Bary (1995) determined the age of the same species in the Persian Gulf waters off Qatar as 18 years using scales' readings for length range 14-74.5 Cm TL and Grandcourt et al. (2004) found that the maximum age of this species was 9.1 years in UAE, but they mentioned that the longevity of *A. spinifer* may have been underestimated as there was a small number of fish in the sample that were close to the maximum size for this species.

Analysis of residual sums of squares indicated no significant difference between the sex-specific length-weight relationships of *A. spinifer* in the western Arabian Sea, consequently a power regression was applied to the length-weight data of all individuals combined. A negative allometric growth was observed for king soldier bream, as the value of (b) was deviated significantly from the value 3 (95% Confidence Interval = 2.798-2.869). The maximum growth in weight was observed in the fourth year of life for king soldier bream which means that this species should be protected until its fourth year of life to achieve a reasonable commercial weight. The same findings were recorded in the previous studies (Druzhinin, 1975; Edwards et al., 1985; El-Sayed and Abdel-Bary, 1995; Grandcourt et al., 2004; Al-Mamry et al., 2009; Raeisi et al., 2011).

A likelihood ratio test (LRT) showed no significant difference between male and female VBGFs growth curves. The VBG parameters calculated in this study showed that *A. spinifer* is a relatively fast growing, short-lived species (Fig. 10). Al-Mamry et al. (2009) gave VBG parameters for the same species in the same area as L∞ = 64.6 cm and K = 0.142 per year. These results were unacceptable where the maximum observed lengths recorded by those authors were 68 cm for males and 70 cm for females, this is may be due to the overestimated age determination. On the other hand, the growth parameters of this species were estimated in the Gulf of Aden, Yemen by two authors (Druzhinin, 1975; Edwards et al., 1985) but the resultant values were highly significant different. Edwards et al. (1985) estimated K = 0.21 per year and L∞ = 57.8cm FL which consistent with our results, while Druzhinin (1975) gave values of 0.077 per year for K and 96.4 cm TL for L∞. El-Sayed and Abdel-Bary (1995) in the Persian Gulf off Qatar, gave K = 0.089 per year and L∞ = 81 cm, while Grandcourt et al. (2004) determined the growth parameters as K = 0.224 per year and L∞ = 52.4 cm FL in the Persian Gulf off UAE.

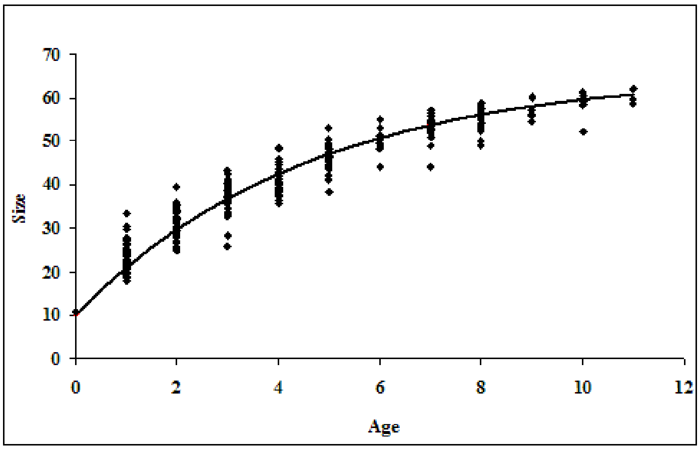

Figure 10: Von Bertalanffy growth model for *A. spinifer* from Arabian Sea

Both of fishing mortality and exploitation rate was high indicating the high level of exploitation. Gulland (1971) suggested that the optimum exploitation rate for any exploited fish stock is about 0.5, at F_{opt} = M, while Pauly (1987) proposed a lower optimum F that equals to 0.4 M. In the present study, F was higher than the F_{opt} given by both Gulland (1971) and Pauly (1987) indicating that the stock of *A. spinifer* in the Arabian Sea (Omani waters) is heavily exploited.

It was found that, about 44% of sampled fish were immature as well as, the length at first capture was smaller than the length at first maturity which means that the exploited *A. spinifer* must be protected till in order to share at least once in the spawning activity. Therefore, mesh sizes used should be increased to catch fish of about at least 33 cm length. Al-Mamry et al. (2009) gave a higher L_{50} and age at first maturity for the same species in the Arabian Sea as 36.5 cm and 5.0 years for males and 37.2 cm and 5.6 years for females, respectively.

The yield per recruit analysis revealed that the stock of king soldier bream in the Arabian Sea seems to be highly exploited as the current F is higher than the defined values of reference points $F_{0.1}$ and F_{max} (0.22 and 0.35 respectively). Also, the current used mesh sizes along with the illegal ones had a negative impact of this stock. To sustain this valuable fishery resource some management regulations, including reduction of fishing pressure especially on spawners and juveniles and increasing the length at first capture should be implemented. Defining and protecting specific critical areas such as nursery and spawning grounds are recommended. Finally, it is important to establish some form of cooperation among fishermen, scientists, and government agencies for implementing sustainable management programmes.

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