

## Length based growth and stock assessment of the longnose trevally *Carangoides chrysophrys* (Cuvier, 1833) from the Arabian Sea coast of Oman

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### ABSTRACT

A study on the growth and stock assessment of the longnose trevally, *Carangoides chrysophrys* (Cuvier) was conducted using length-frequency data collected during April 2005 – March 2007 from the Arabian Sea coast of Oman. The size of *C. chrysophrys* in commercial catches ranged from 21 to 72 cm TL and about 52% of the fish belonged to the 0-1 year age group. The length-weight relationship was  $W = 0.0369L^{2.7123}$  ( $R^2 = 0.967$ ). The von Bertalanffy growth (VBG) parameters estimated for the species were:  $L_{\infty} = 75.6$  cm,  $K = 0.47$   $y^{-1}$  and  $t_0 = -0.37$  y, and the life span appeared to be 8-9 years. The annual total mortality (Z), natural mortality (M) and fishing mortality (F) coefficients stood at 1.2, 0.74 and 0.46, respectively. The exploitation rate (E) was 0.38. While the average standing stock was estimated at 2,633 t, the total stock was 4,455 t. The estimates of MSY varied from 1,363 to 1,580 t. At the current F, the  $Y_w/R$ , TB/R and SSB/R were 236 g, 653 g and 364 g respectively. The study indicates scope for development of artisanal fishery for *C. chrysophrys* in the Arabian Sea off Oman.

Keywords: Arabian Sea, *Carangoides chrysophrys*, Growth, Oman, Stock assessment

### Introduction

The family carangidae comprises about 32 genera and 140 species in the world oceans (Nelson, 1994). Among the carangids of the genus *Carangoides* represented by 11 species in Omani waters (Fouda *et al.*, 1997), the longnose trevally *Carangoides chrysophrys* (Cuvier) is an important constituent of the demersal fisheries of the country. Longnose trevally is a moderate sized fish distributed in the Indo-West Pacific from the coast of east Africa to Fiji, in the north to Japan, and south to New Zealand (Randall, 1995; Lin and Shao, 1999). Along the coasts of Oman, the longnose trevally inhabits relatively inshore waters up to the depth of 60 m in the southern Arabian Sea and Gulf of Oman (Al-Abdessalaam, 1995). It supports both commercial and artisanal fisheries. The gears employed in the fishery include handlines, gillnets, baited traps and longlines. Longnose trevally is also harvested by foreign vessels with bottom trawls (Stengel and Al Harthy, 2004). The estimated contribution of *C. chrysophrys* from the Arabian Sea coast of Oman during 2005-2006 stood at 1,216 t and during 2006-2007 at 1,206 t (GoSO, 2007; 2008).

In spite of its commercial importance, no information is available on the age and growth as well as population characteristics of *C. chrysophrys* from Oman waters. In

the present study, using the length frequency data, an attempt has been made to estimate the age, growth and stock status from the Arabian Sea coast of Oman to help develop a management plan for sustainable harvest.

### Materials and methods

#### Study area

Along the Arabian Sea coast of Oman, traditional fishing gears (handlines, gillnets, traps, longlines, shore seines and cast nets) are operated in the coastal waters up to a depth of 40 m between Ras-al Hadd (Sharqia) in the north and Salalah in the south and the demersal trawlers fish in offshore areas beyond 10 nautical miles from the shore or beyond 50 m depth between 21° 50' N, 59° E and 17° 50' N, 55° E (Fig. 1).

For the study, a total of 4,476 fish (1,292 from artisanal gear; 3,184 from trawl) were measured at random for total length (TL) to the nearest 1 mm, on monthly basis, between April 2005 and March 2007. The unsexed pooled length data from all the gears were grouped into 20 mm class interval to estimate growth. Length at first capture ( $L_c$ ) was estimated by plotting cumulative percentages of fish against length classes.

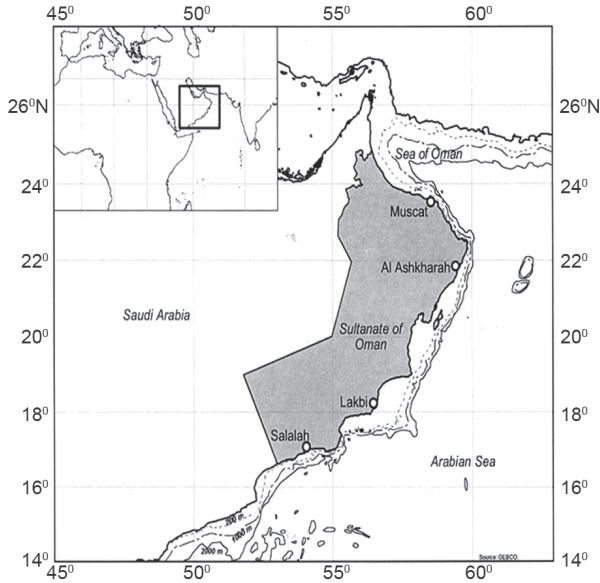


Fig. 1. Map showing the Arabian Sea and Gulf of Oman coasts

To calculate length-weight relationship, 641 unsexed fish were measured for their TL to the nearest 1 mm and weighed to the nearest 1 g. The general equation is;

$$W = aL^b$$

where, W is the total weight, L is the total length and 'a' and 'b' are the constants to be determined.

To estimate growth parameters ( $L_\infty$ , K and  $t_0$ ) of fish, the monthly length frequency data (N= 4,476) were fitted to the von Bertalanffy growth (VBG) equation,

$$L_t = L_\infty [1 - e^{-K(t-t_0)}]$$

where  $L_t$  = length at age t;  $L_\infty$  = asymptotic length; K = growth coefficient; t = age of the fish and  $t_0$  = hypothetical age at which fish would have zero length. Estimations were made using non-seasonal version of ELEFAN 1 technique available with the LFDA version 5.0 of FMSP-Fish Stock Assessment Software (Hoggarth *et al.*, 2006). The overall growth performance index (Munro's phi prime index,  $\Phi'$ ) for *C. chrysophrys* was calculated empirically (Munro and Pauly, 1983) using the formula,

$$\Phi' = \log_{10} K + 2 \log_{10} L_\infty$$

where K is expressed on annual basis and  $L_\infty$  in cm.

The instantaneous total mortality rate (Z) of fish was estimated by the length converted catch curve method (Pauly, 1983) using the routine provided in the LFDA version 5.0 of FMSP software. Natural mortality coefficient (M) of fish was estimated by three different empirical methods (Rikhter and Efanov, 1976; Pauly, 1980; Alagaraja, 1984) and the average M was taken for further analyses. In

the empirical method of Pauly (1980), temperature was taken as 24 °C that represents the mean bottom water temperature in the Arabian Sea off Oman (Thangaraja, 1995). In Rikhter and Efanov's method (1976), the formula,

$$M = 1.521 / t_m^{0.72} - 0.155$$

was used, where,  $t_m$  = the age at which 50% of the population matures.

Alagaraja's (1984) method assumes that 99% of a cohort had died if it had been exposed to natural mortality only. The formula used was:

$$M1\% = -\ln(0.01)/T_m$$

where,  $T_m$  is longevity and M1% is natural mortality corresponding to 1% survival. The fishing mortality (F) was computed by subtracting natural mortality from total mortality as,

$$F = Z - M$$

The exploitation rate (E) was estimated from Z and F values as defined by the equation (Ricker, 1975; Sparre and Venema, 1992) as,  $E = F/Z$ . The exploitation ratio (U) was estimated by the equation (Beverton and Holt, 1957; Ricker, 1975) as,  $U = F / Z (1 - e^{-z})$

The pooled annual average catch of *C. chrysophrys* during 2005-06 and 2006-07 was considered as yield (Y). The standing stock of fish was estimated using the formula,

$$\text{Standing stock} = Y/F$$

where Y, the yield and F, the fishing mortality. The total stock was calculated by the relation between yield and exploitation ratio as,

$$\text{Total stock} = Y/U$$

where Y is the yield and U, the exploitation ratio. The maximum sustainable yield (MSY) of *C. chrysophrys* was estimated using Cadima's formula as:  $MSY = 0.5 * (Y + M * B)$

where Y is the average annual catch; B, the average biomass for 2005-2006 and 2006-2007 and M, the natural mortality. The MSY was also estimated by the routine of the predictive Thompson and Bell model incorporated in the YIELD software (Hoggarth *et al.*, 2006). All the required input parameters for the YIELD software were obtained from the present study and from parallel studies on the biology of *C. chrysophrys* by the authors. For the stock-recruitment relationship (SRR), Beverton and Holt SRR was adopted. To predict the yield and biomass for a range of F values, the Thompson and Bell analysis was carried out. The yield-per-recruit (Yw/R), total biomass-per-recruit (TB/R), stock spawning biomass-per-recruit (SSB/R) and fishable biomass-per-recruit (FB/R) for a range

of F-values were also estimated using the YIELD package incorporated in the FMSP Software (Hoggarth *et al.*, 2006). The optimum length of exploitation was estimated empirically from the equation (Froese and Binohlan, 2000) as,

$$L_{opt} = 3 * L_{\infty} / 3 + M / K$$

where  $L_{opt}$  denotes the optimum length of exploitation,  $L_{\infty}$  the asymptotic length, M, the natural mortality and K, the growth coefficient.

**Results**

The size frequency of *C. chrysophrys* in the commercial catches during 2005-2007 ranged between 21 and 72 cm TL. The cumulative percentage contribution of fish measuring up to 26 cm was 5.1% which increased to 22.2% in 27-28 cm group. The length at which 50% of fish was caught ( $L_c$ ) was 53.8 cm TL for artisanal gears and 28 cm TL for industrial trawlers (Fig. 2). For the data pooled from both the sectors, the length at first capture was estimated at 34 cm TL.

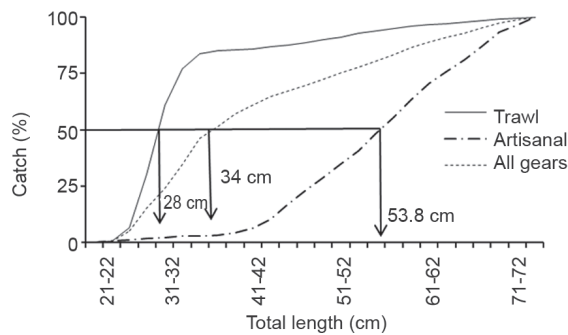


Fig. 2. Length at capture of *C. chrysophrys*

The optimum length of exploitation ( $L_{opt}$ ) estimated was 49.6 cm. The value of  $L_{opt}/L_{\infty}$  calculated was 0.66.

The length-weight relationship in unsexed fish (Fig. 3) was estimated as,  $W = 0.0369L^{2.7123}$  ( $R^2 = 0.967$ ).

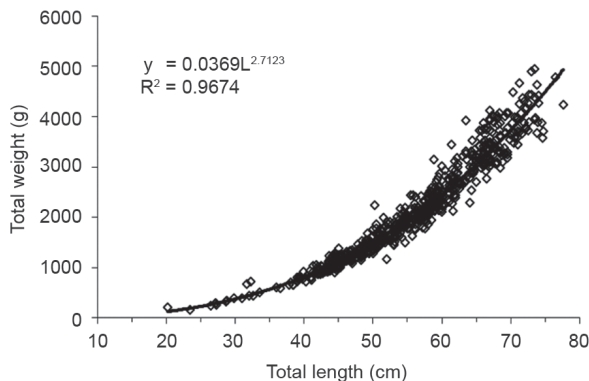


Fig. 3. Length-weight relationship in *C. chrysophrys*

The estimated  $L_{\infty}$ , K and  $t_0$  were 75.63 cm, 0.467  $y^{-1}$  and -0.371 y, respectively. The growth curves fitted by ELEFAN 1 are presented in Fig. 4.

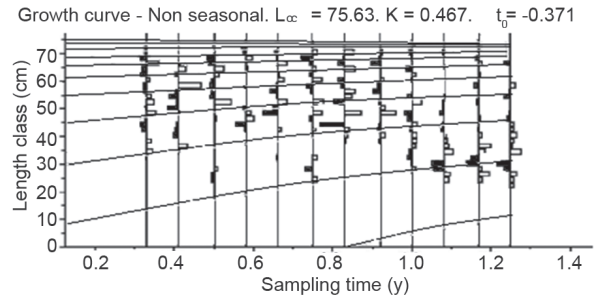


Fig. 4. VBG curves of *C. chrysophrys* fitted by ELEFAN technique

There was a general decrease in the rate of growth as the age of fish increased (Fig. 5). The fish attained lengths of 35.8, 50.6 and 60 cm at the end of the first, second and third years of life respectively. The fish attained the length of 74.1 cm at the end of eighth year indicating the life span of *C. chrysophrys* would be around 8-9 years in the Omani waters and growth performance index ( $\phi'$ ) was 3.43.

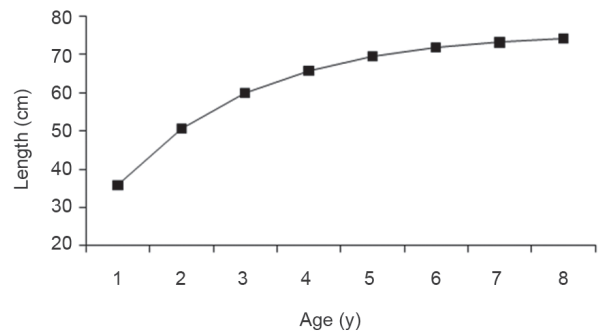


Fig. 5. VBG curve of *C. chrysophrys* fitted by ELEFAN technique

Though, the commercial catches were contributed by fish of 0-6 years of age (Fig. 6), the dominant groups appeared to be 1-4 years of age.

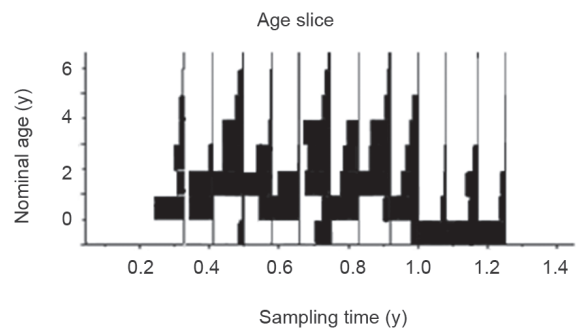


Fig. 6. Age distribution of *C. chrysophrys* in commercial catches

The total mortality ( $Z$ ) was estimated to be  $1.2 \text{ y}^{-1}$  ( $SE=0.018$ ). The natural mortality ( $M$ ) calculated by empirical methods of Pauly (1980), Alagaraja (1984) and Rikhter and Efanov (1976) were 0.8, 0.58 and 0.83 respectively with the average of  $0.74 \text{ y}^{-1}$ . The fishing mortality ( $F$ ) was estimated as  $0.46 \text{ y}^{-1}$ . The exploitation rate ( $E$ ) calculated as 0.38 indicated the stock of *C. chrysophrys* is underexploited. The value of  $U$  estimated was 0.27. From the average annual yield of 2005-06 and 2006-07 (1,211 t), the standing stock was estimated at 2,633 t and the annual total stock at 4,485 t. The MSY calculated by Cadima's formula stood at 1,580 t.

The Thompson and Bell analysis indicated a lower MSY of 1,363 t which can be harvested at the  $F$ -factor 1.5 (*i.e.*, current  $F = 1$ ) (Fig. 7). As the current yield is 1,211 t, there would be scope only to marginally increase the catch by 152 t. The predicted total biomass decreased from 8,013 t to 6,264 t at  $F$  of 0.25 and to 3,705 t at  $F = 1$ . At  $F$ -factor 4, the biomass reduced to 226 t.

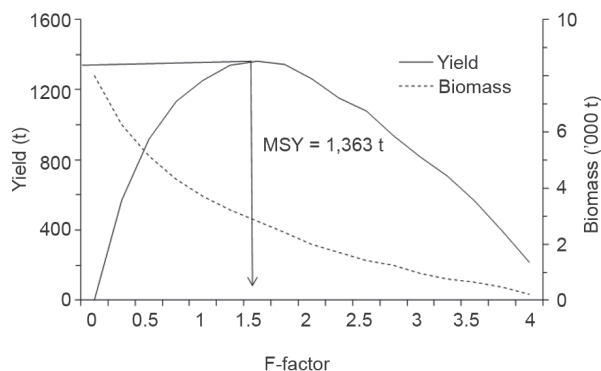


Fig. 7. Predicted total biomass and yield of *C. chrysophrys* for a range of  $F$

Yield-per recruit ( $Y_w/R$ ) and total biomass-per-recruit (TB/R), spawning stock biomass-per-recruit (SSB/R) and fishable biomass-per-recruit (FB/R) of *C. chrysophrys* were calculated for  $F$ -values ranging from 0-2 (Fig. 8). The highest  $Y_w/R$  of 298 g was obtained at  $F$  of 1.4 which is almost three times the present level of  $F$  (*i.e.*, 0.46). When  $F$  was zero, the estimated TB/R, SSB/R and FB/R were 1,289 g, 904 g and 1,100 g respectively which decreased with the increase in  $F$ . At the current  $F$  (0.46), the values of  $Y_w/R$ , TB/R, SSB/R and FB/R were 236 g, 653 g, 364 g and 517 g respectively.

## Discussion

As the maximum size of fish ( $L_{max}$ ) measured in the present study was 72 cm TL, the estimated  $L_{\infty}$  of 75.63 cm TL is reasonable. However, from coasts of Iran in the Persian Gulf and Sea of Oman, the  $L_{max}$  has been reported as 60 cm TL (Froese and Pauly, 2011). This indicates that the species *C. chrysophrys* would be growing to larger size

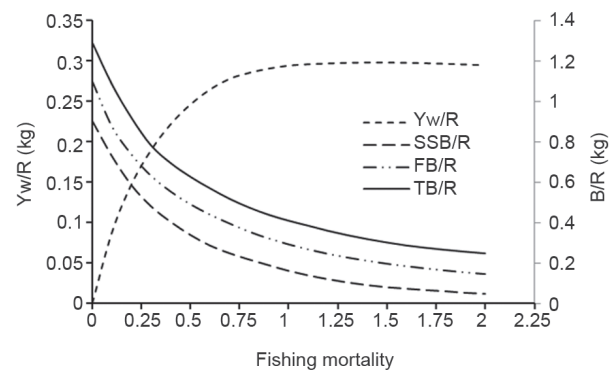


Fig. 8. Yield-per-recruit and biomasses-per-recruit in *C. chrysophrys* against  $F$

( $Y_w/R$ , yield-per-recruit; SSB/R, stock spawning biomass-per-recruit;

FB/R, fishable biomass-per-recruit; TB/R, total biomass-per-recruit)

in the Arabian Sea due to the higher productivity and favourable environmental conditions.

The study indicated that about 65% of all fish caught from the Arabian Sea were below the length at first maturity (Al-Marzouqi *et al.*, 2009). While, the artisanal gears landed about 90% of the catches above the average length at first maturity indicating appropriate capture techniques, the industrial trawlers caused growth overfishing. As regulations were needed for the industrial trawlers to protect the stock of *C. chrysophrys* in the Arabian Sea, the total ban of industrial trawler activity since June 2011 has negated the concern of overfishing paving the way for artisanal fisheries development in the country.

Allometric growth pattern is common among carangids such as *Megalaspis cordyla*, *Decapterus russelli*, *Caranx carangus*, *Selaroides leptolepis*, *Atropus atropus*, *Alepes kalla*, *Alepes djedaba* and *Atule mate* along the Indian coasts (Reuben *et al.*, 1992; Kalita and Jayabalan, 1997) and *Carangoides bajad* as well as *Gnathanodon speciosus* in the UAE waters (Grandcourt *et al.*, 2004). In the present study, the 'b' value of 2.712 also suggests allometric growth pattern.

The  $\emptyset'$  value enables a comparison of growth between the stocks of a species or between related species. Based on the values of  $\emptyset'$ , it has been suggested that the carangids are fast growing fishes (Grandcourt *et al.*, 2004). The  $\emptyset'$  values ranged from 2.38 to 3.34 in several species of carangids in Philippines and India (Corpuz *et al.*, 1985; Reuben *et al.*, 1992). In the Gulf of Aden, the  $\emptyset'$  value for *Gnathanodon speciosus* was 3.45 (Edwards *et al.*, 1985) and for *Carangoides bajad* and *G. speciosus* from the southern Arabian Gulf, the values were 3.13 and 3.43 respectively (Grandcourt *et al.*, 2004). Hence, the higher

value of  $\emptyset'$  for *C. chrysophrys* (3.43) and the K value of 0.47 estimated in the present study indicate that the species grow faster in Arabian Sea coast of Oman.

In the present study, the estimate of natural mortality (M) taken as the average of three empirical methods ( $0.74 \text{ y}^{-1}$ ) might be a better estimate. As the natural mortality (M) is associated with the lifespan of the fish and the latter is linked to growth coefficient K, the M/K ratio is almost constant among closely related species and sometimes within the similar taxonomic groups (Beverton and Holt, 1959; Banerji, 1973). In fishes, the M/K ratio mostly ranges from 1 to 2.5 (Beverton and Holt, 1959). In the present study, the M/K ratio estimated for *C. chrysophrys* was 1.59.

For any fish stock, exploitation rate (E) close to 0.5 is assumed to be the optimum level and it is further assumed that the sustainable yield is optimised when  $F \approx M$  (Gulland, 1971). The estimated E of 0.38 for *C. chrysophrys* and the discontinued activity of industrial trawlers that caused growth overfishing since June 2011, indicate scope for increase of effort in the artisanal sector.

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