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Biology and fishery of the bullet tuna, *Auxis rochei* (Risso, 1810) in Indian waters

S. JASMINE, PRATHIBHA ROHIT, E. M. ABDUSSAMAD, K. P. SAID KOYA, K. K. JOSHI, S. KEMPARAJU, D. PRAKASAN, M. N. K. ELAYATHU AND MANJU SEBASTINE

Central Marine Fisheries Research Institute, Kochi - 682 018, Kerala, India.
e-mail: jasminevzm@rediffmail.com

ABSTRACT

Auxis rochei, popularly known as the bullet tuna, is the smallest of all tuna species available in Indian waters. Its distribution is reported from all maritime states but it forms a fishery of commercial importance only in the south-west region (Kerala, Tamil Nadu and Karnataka) with targeted fishery being carried out in southern Kerala. The average annual catch (2006-2010) is estimated at 3,131 t, constituting 2.8% of the total tuna landings. Commercial exploitation is mainly by gillnets and small hook and lines with the 0-1 yr old fishes comprising bulk of the commercial catch. The length-weight relationship was estimated as $W=0.0076L^{3.249}$ with no significant difference between the sexes. Size at first maturity was estimated at 23.6 cm and fecundity estimated was 12,03,258. *A. rochei* spawns throughout the year with peak during July-September. Zooplankton, fishes and crustaceans were the dominant food items recorded. The von Bertalanffy growth parameters estimated were L_{∞}= 42.3 cm, K= 0.61 yr^{-1} and t_0= -0.0337. Mortality estimates were M=1.18 and Z=5.90 and F=4.72 with a high exploitation rate of E=0.80, calling for appropriate management measures to be adopted for continued exploitation at sustainable levels.

Keywords: Age and growth, *Auxis rochei*, Bullet tuna, Exploitation, Food and feeding, Maturity

Introduction

Auxis rochei (Risso, 1810), known popularly as the bullet tuna, is the smallest among all tuna species in the world. Fish of the genus *Auxis,* are epi/meso-pelagic, having a worldwide distribution in tropical and subtropical waters with a seasonal coastal distribution in temperate and tropical areas (Uchida, 1981; Collete, 1986). The occurrence of the species has been recorded along both the coasts of India but it is harvested on a commercial scale mainly in the south-west region. Very little is known on the fishery and biology of *A. rochei* and exploitation of this coastal species along the Indian coast was minimal till the late eighties. However, with popularisation of motorised crafts, exploitation and catch by these crafts registered a steep increase. Along southern Kerala, *A. rochei* has become a major species in the fishery (Gopakumar *et al*., 1994) and is exploited on a commercial scale throughout the year. The average annual catch (2006-2010) is estimated at 3,131 t contributing 1.7% to the total tuna landings.

Several investigators (Uchida, 1981; Rodriguez-Roda, 1983; Grudtsev, 1992; Bök and Oray, 2001; Macias *et al*., 2005; Macias *et al*., 2006; Palandri *et al*., 2008; Valeiras *et al*., 2008; Kahraman *et al*., 2010) have studied age determination, length at first maturity, gonado-somatic index, sex ratio, and the spawning period of the species. Fishery, spawning areas and the behaviour patterns of the schools have also been investigated from other parts of the globe (Yoshida and Nakamura, 1965; Ishida, 1971; Yesaki and Arce, 1994; Sabatésand Recasens, 2001; Oray *et al*., 2005; Oray and Karakulak, 2005). Studies on the biology of *A. rochei* exploited in India are limited and include those of Silas (1969), Muthiah (1985), Gopakumar and Sarma (1989) and James *et al*. (1993). The present study was taken up to get detailed information on the fishery, biology, growth and exploitation of bullet tuna on a national level.

Material and methods

The study was conducted for a period of five years during 2006-2010. Data on catch, effort, species composition of tuna and biological information of *A. rochei* were collected at weekly intervals from major landing centres on the Indian mainland coast following Stratified Random Sampling Technique developed by CMFRI. Length measurements (fork length, FL) were taken at the landing centres and were raised to the monthly/annual catches. This formed the basic data for estimating growth and population structure using length based models. The length-weight relationship as suggested by Le Cren (1951) was calculated by regression analysis. The sex and gonad maturity stages were assessed from structure and size of gonads and classified as per the ICES scale adopted by

Wood (1930). Fishes in stages IV and V alone were considered for estimating fecundity. The ovaries were preserved in 5% formalin and fecundity estimates were made using ova samples from the anterior, central and posterior part of each ovary. Mature ova were counted and the total fecundity was estimated per unit body weight of the fish. Minimum size at maturity was fixed as the length when 50% of the fishes were found to be mature, and was determined using logistic curve (Lockwood, 1988; King, 1996).

Food and feeding habits were studied by stomach content analysis. Stomach fullness was visually classified into five categories as full, three-fourth full, half full, one-fourth full and empty, based on the distension of the stomach due to the presence or absence of food. (Bapal and Bal, 1958). For each item, identifiable organs were used to determine the number of prey present in the stomach. Prey was identified up to genus level and further to species level whenever possible using keys and descriptions found in Smith and Heemstra (1986), Fischer and Whitehead (1974) and by comparison with material available in the reference collections.

Growth parameters *viz.,* asymptotic length (L_∞) and growth co-efficient (K) were estimated using the ELEFAN I module of FiSAT software and the Powell–Wetherall plot (Gayanilo *et al*., 1996). The length based growth performance index ϕ was calculated from L_∞ and K as in Pauly and Munro (1984). The probability of capture and size at first capture (Lc) were estimated as in Pauly (1984) and the age at zero length (t_0) from Pauly's empirical equation (Pauly, 1979). Natural mortality (M) was calculated by Pauly's empirical formula (Pauly, 1980) and total mortality (Z) from length converted catch curve (Pauly, 1983b). Longevity was estimated as $t_{max} = 3/K + t_0$ (Pauly, 1983a).

Length structured virtual population analysis (VPA) was used to obtain fishing mortalities per length class. Exploitation rate was estimated from the equation, $E = F/Z$ and exploitation ratio from $U = F/Z*(1\text{-}e^{-z})$; where, F is the fishing mortality rate.

Total stock (P) and biomass (B) were estimated from the ratios Y/U and Y/F respectively; where Y is the annual average yield in tonnes. Maximum sustainable yield was calculated as in Gulland (1979) for exploited fish stocks. The relative yield per recruit (Y/R) and biomass per recruit (B/R) at different levels of F was estimated using Beverton and Holt model (Beverton and Holt,1957; Gayanilo *et al*., 1996).

Results

Distribution and fishery

Bullet tuna are distributed along the west and east coasts of India, with large concentration along the southern parts, especially along the coasts of Kerala, Tamil Nadu and Karnataka. They are found in neritic and oceanic waters with high abundance, especially of adults, in deeper waters associated with knolls and oceanic ridges and often form large schools. They are exploited mainly by crafts deploying hooks & lines and gillnets. Trawls, ring seines and purse seines landed *A.rochei* occasionally (Fig.1). The annual catch during 2006-2010 ranged between 1,835 (2008) and 6,556 t (2010) with an average catch of 3,131 t forming 4.1% of the coastal tuna catches and 2.8% of the total tuna catch of the country (Fig. 2). Landings peaked in 2006, then registered a downward trend initially and thereafter increased in 2010. Target fishing for bullet tuna using longlines and handlines, driven by local demand, prevailed only along the southern districts of Kerala. Major fishery was restricted to the southern most part of Indian waters with nearly 68.4% of the landings from Kerala alone, 20.8% from Tamil Nadu and 5.6% from Karnataka (Fig. 3). Landings were observed throughout the year, with peak landing in June (13.8%) and November (13.6%) (Fig. 4).

Length composition

The commercial landing was supported by fishes of 14 to 40 cm FL (Fig. 5). Fishes in the length rage of 22-26 cm dominated the catch and contributed 82% of the catch. Major mode was at 24 cm and the annual mean length was estimated at 25.3 cm.

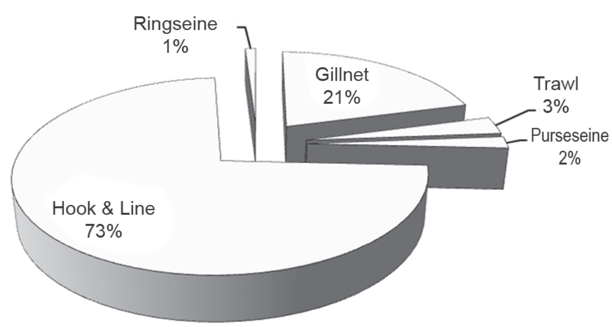

Fig. 1. Contribution of different gears to the total landings of *Auxis rochei* in India

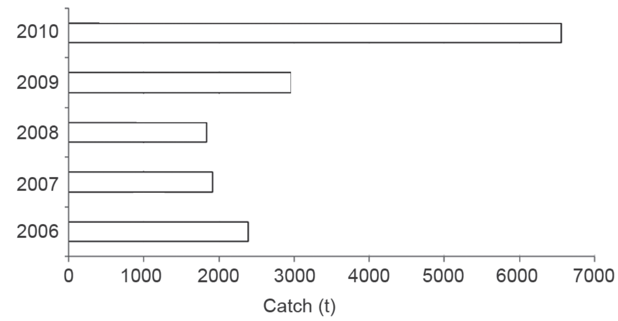

Fig. 2. Annual all India landings of *Auxis rochei* (2006-2010)

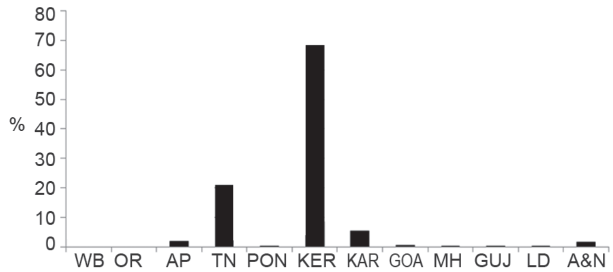

Fig. 3. Contribution (%) of different maritime states and islands to total *Auxis rochei* production in India

WB : West Bengal; OR : Odisha; AP : Andhra Pradesh; TN : Tamil Nadu; PON : Puducherry; KER : Kerala, GOA : Goa, MH : Maharashtra; GUJ : Gujarat; LD : Lakshadweep; A&N : Andaman & Nicobar Island

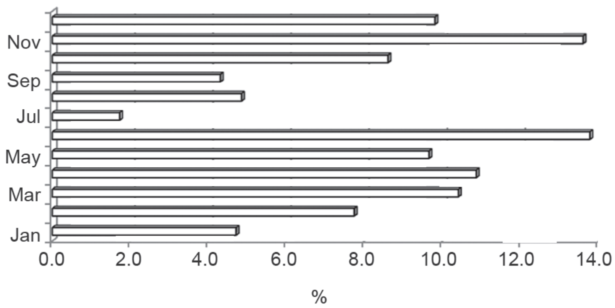

Fig. 4. Seasonal abundance of *Auxis rochei* (2006-2010)

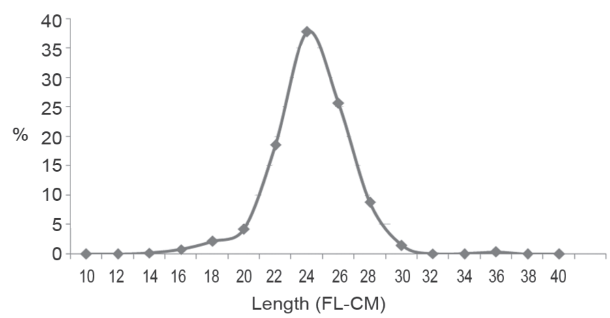

Fig. 5. Length frequency (FL- cm) distribution of *Auxis rochei* during 2006-'10

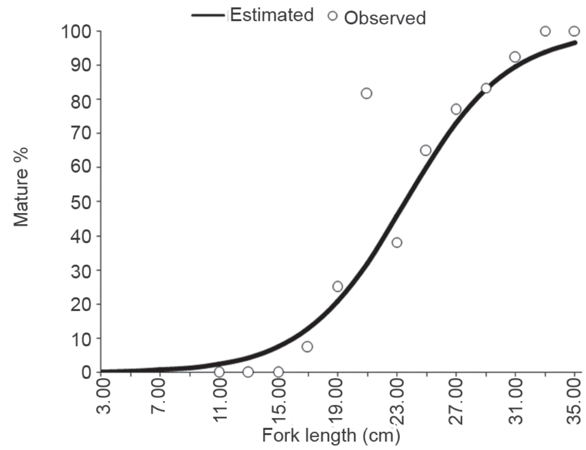

Fig. 6. Size at first maturity estimated for *Auxis rochei*

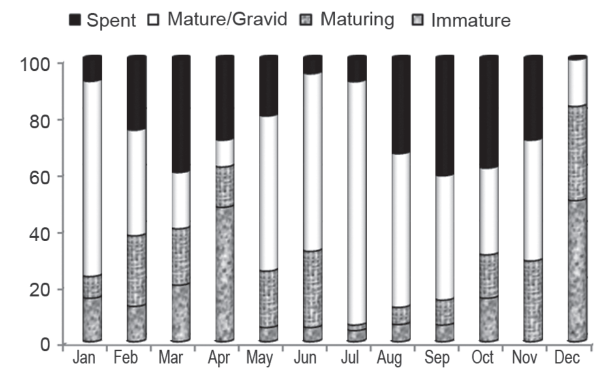

Fig. 7. Seasonal changes in gonadal maturiy of *Auxis rochei*

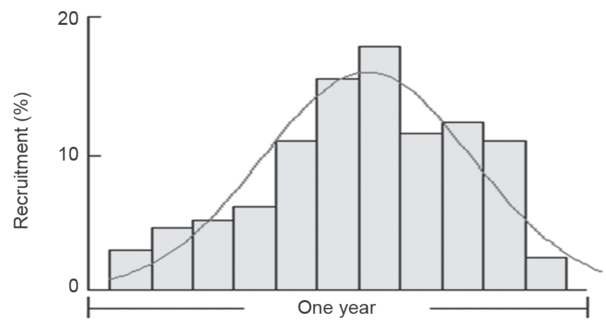

Fig. 8. Recruitment pattern in *Auxis rochei*

Maturity, fecundity, spawning and recruitment

The size at first maturity for *A. rochei* was estimated at 23.6 cm (Fig. 6). Spawning was observed round the year with peaks in July and January (Fig. 7). Recruitment was observed throughout the year with peaks in July and August when more than 60% recruits entered the fishery (Fig. 8). The fecundity was estimated at 12,03,258 eggs per kg body weight.

Food and feeding

Feeding intensity was low for the species with none of the sampled fish having gorged or full stomach condition. Stomachs in empty condition were dominant and contributed 60.3%. Food preference indicated *A. rochei* to be a nonselective generalist feeder foraging mainly on small crustaceans, finfishes and molluscs. The larval and juvenile stages of crustaceans and fishes contributed considerably to the diet. Crustaceans mainly included *Acetes* spp, followed by other penaeid prawns and crabs. Fishes were represented by anchovies, sardines and mackerel. Gastropods and cephalopods represented the molluscan component in the diet.

Growth

Growth was allometric and the length-weight relationship derived is $W = 0.0076\ L^{3.243}$ where 'W' is the weight of fish in g and 'L' is the fork length in cm.

The von Bertalanffy growth equation was derived as $L_t = 42.3\ [1\text{-}e^{-0.61(t-0.0337)}]$. The asymptotic weight obtained was 1,429 g, the growth performance index 3.0 and longevity 4.9 years. The length attained by the fish at the end of 1st, 2nd, 3rd and 4th years were 18.6, 29.3, 35.2 and 38.4 cm respectively. Fishery was sustained mainly by the 1+ yr old fishes (22 to 26 cm).

Mortality, exploitation and VPA

The natural mortality rate (M), fishing mortality rate (F) and total mortality rate (Z) computed were 1.18, 4.72 and 5.9, respectively (Fig. 9). The exploitation ratio was 0.792 and exploitation rate was 0.80. The Beverton and Holt relative yield per recruit (Y/R) and biomass per recruit (B/R) curve analysis showed that E_{max} is 0.421; which is much lower than the present exploitation, indicating that the stock in the present fishing area is under high fishing pressure.VPA indicated that main loss in the stock up to 20 cm size was due to natural causes (Fig.10). Fishes became more vulnerable to the gear after this size and mortality due to fishing increased and eventually outnumbered the natural losses from 23 cm onwards.

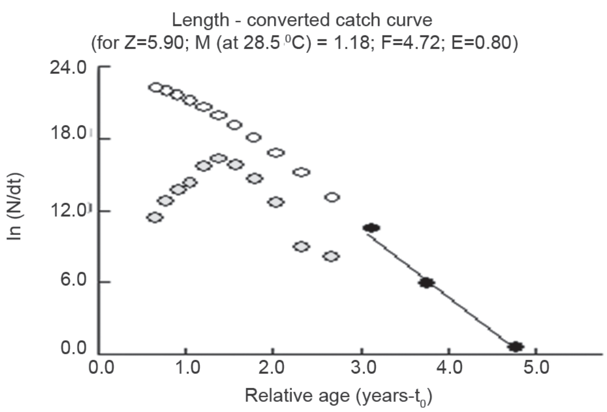

Fig. 9. Mortalities and exploitation rate of *Auxis rochei* estimated using length converted carth curve

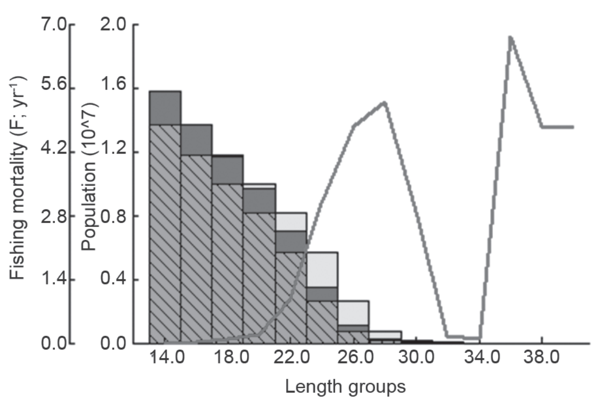

Fig.10. Virtual population analysis for *Auxis rochei*

Stock, MSY and Yield/Recruit

The annual stock, biomass and MSY of *A. rochei* were estimated at 3,924, 663 and 3000 t respectively. The yield and biomass curves showed that the maximum yield and yield/recruit could be obtained by decreasing the present level of fishing by 50% (Fig. 11).

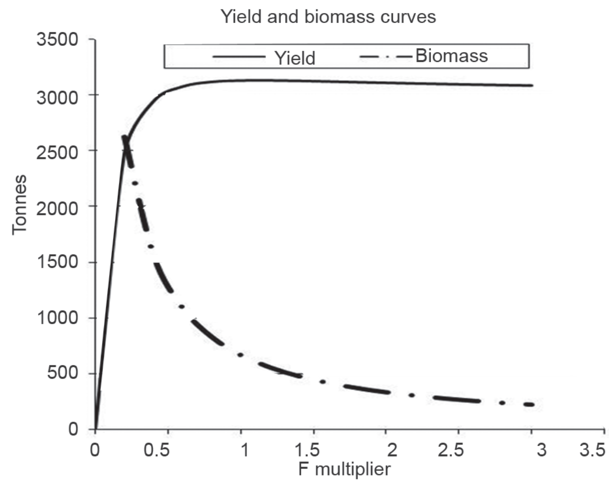

Fig.11. Yield and biomass per recruit curves for *Auxis rochei*

Discussion

Bullet tunas have a distribution along all the states but it formed a significant part of the tuna catch only in the southern coast (Kerala, Tamil Nadu, Karnataka). A similar observation has been made earlier (Muthiah, 1985; Gopakumar and Sarma, 1989; James and Pillai, 1993; James *et al*.,1993; Gopakumar *et al*.,1994; Pillai *et al*., 2002; Pillai *et al*., 2003; Pillai and Gopakumar, 2003; Gopakumar and Ajithkumar, 2005). This tuna species is highly preferred along coastal southern Kerala and fetches a good price in the local domestic market. Targeted fishing is carried out in this region to exploit the available stock, and the landings made in other regions too are transported to and marketed in southern Kerala. Fishing for *A. rochei* in this region is therefore more market driven under demand from locals. The fishery is mainly sustained by 1+year old fishes weighing 0.5 to 0.7 kg.

A. rochei attained maturity at 23.6 cm FL, when the fish is around 2 years old. The estimated maturity size is smaller than the estimated Lc (17 cm); providing the fish a chance to spawn before it becomes susceptible to fishing. The length at first maturity (23 cm) obtained in the present study is comparable to the estimate in an earlier study made by Muthiah (1985) for fishes exploited along Mangalore (Karnataka) coast. However, it is much smaller than the sizes (35 cm and 38 cm) estimated by Rodriques-Roda (1966) and Rodriguez-Roda (1983) for *A. rochei* captured in Spanish waters. Macias *et al*. (2005) too have suggested that *A. rochei* attain maturity at 35 cm FL. The age at maturity has been estimated at 2 years which is slightly less than the age estimated in the present study. The present as well as earlier studies (Megalophonou *et al.*, 2000; Niiya, 2001; Macías *et al.*, 2005) have shown that fecundity of *A. rochei* is very high and it is a multiple spawner with asynchronous oocyte development. Peak spawning is during the summer months when warm waters prevail in the region. The spawning period in the Mediterranean has been reported to occur from June to September (Ehrenbaum, 1924; Piccinetti *et al.*, 1996; Macías *et al.*, 2005) and between May and September in the Turkish waters (Kahraman, 2010). Spawning off Mangalore is during September–December (Muthiah *et al.,* 1985). Jones and Kumaran (1963) opined that the areas between Madagascar and the coast of Africa are the possible spawning grounds for this species. *A. rochei* is reported to spawn in August off Kaena Point, Oahu (Yoshida and Nakamura, 1965) and in late June in the waters off Kochi Prefecture and off Taiwan (Hamada *et al.*, 1973).

Muthiah (1985) estimated the fecundity of *A. rochei* to range from 52,570 (25.2 cm FL) to 1,62,777 (33.7 cm FL). Silas (1969) estimated the fecundity to vary from 31,000 to 1,03,000 with an average of 52,000 ova per spawning. According to Macías *et al.* (2005) bullet tuna has an indeterminate fecundity pattern which necessitates dependency on estimates of batch fecundity and spawning frequency to determine potential annual fecundity (Hunter and Macewitz, 1985; Hunter *et al.*, 1992). The estimates of relative batch fecundity for this species obtained by Niiya (2001) in the Pacific Ocean were around 52 oocytes per g body mass. Macias *et al*. (2005) estimated the average fecundity of *A. rochei* as 2, 33,941 oocytes by spawning batch and the relative fecundity was 242 oocytes per g of body mass. The present study also indicated higher relative fecundity (12,03,258 per kg body weight).

A. rochei mainly fed on small fishes, molluscs and crustaceans. Mostarda *et al*. (2007) reported that the bullet tuna is an epipelagic off-shore predator feeding on whatever abundant resources is available in the environment, with a preference for planktonic crustaceans, small cephalopods and fish larvae.

Growth of the species has been studied in same regions of the world. The estimates of the constants 'a' and 'b' in the length-weight relationship in earlier studies are given in Table 1. The fish has been reported to follow allometric growth with the 'b' value close to three except in the study reported by Kahraman *et al*. (2011).

The present study revealed fast growth for *A. rochei* with a maximum life span of 5 years. Studies conducted elsewhere showed comparable values of L_∞ ranging between 41.4 and 57.4 cm FL (Table 2). The differences observed in the total growth may be due to changes in the environment. However De la Serna *et al*. (2005) estimated

Table 1. Estimated 'a' and 'b' values in the length-weight relationship of *A. rochei*

'a' value	'b' value	Region	Reference
0.00001005	3.129	Gibraltar Strait	Rodríguez- Roda (1966)
0.0076	3.24	Turkish Medit. and Aegean Sea	Bök and Oray (2001)
0.002182	3.561	Spanish Mediterranean	De la Serna *et al*. (2005)
1.60943E-5	3.003	S.Western Spanish Mediterranean	Machias *et al.* (2005)
0.00559	3.29	Western Mediterranean	Macías *et al.* (2006)
0.0014	3.675	Ligurian Sea	Palandri *et al*. (2008)
0.0542	2.685	Turkish Mediterranean	Kahraman *et al.* (2011)
0.0076	3.243	Indian waters	Present study

Table 2. Growth parameters estimated for *A. rochei*

L_∞	k	t_0	Length attained				Region	Reference
			1st yr	2nd yr	3rd yr	4th yr		
41.5	0.320	-0.830	18.4	24.7	29.3	32.7	East Atlantic	Grudstev (1992)
73.2	0.447	-1.020	43.5	54.2	61.1	65.4	West Mediterranean	De la Serna *et al*. (2005)
44.0	0.700	-0.139	24.2	34.2	39.1	41.6	West Mediterranean	Valeiras *et al*. (2008)
47.4	0.292	-2.365	29.6	34.1	37.5	40.0	East Mediterranean	Bök and Oray (2001)
57.4	0.181	-4.155	34.8	38.5	41.6	44.3	Turkish Mediterranean coast	Kahraman *et al*.,(2011)
42.3	0.61	0.0337	18.8	29.6	35.4	38.5	Indian coast	Present study

high L_∞ and k values of 73.2 cm and 0.447 respectively along West Mediterranean coast and Kahraman *et al*. (2011) estimated values of 57.3 and 0.18 in Turkish waters. These values differ from other studies carried out in the Mediterranean waters as well as the results obtained in the present study. The low 'k' value obtained by Kahraman *et al*. (2011) indicated a very slow growth and long life for *A. rochei* which is in contrast with the general opinion of fast growth of the species.

Stock status of *A. rochei* in the present context is not very encouraging. The present exploitation rate is much higher than the E_{max} indicating that the stock is under high fishing pressure and urgent measures are to be taken to reduce the fishing pressure to bring back the stock to healthy levels.

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