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Research Article

Length-based fishery status of yellowfin tuna (*Thunnus albacares* Bonnaterre, 1788) in the northern waters of the Oman Sea

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Abstract

In the present study, population characteristics of *Thunnus albacares* were evaluated by sampling at five fish landing sites in the northern Oman Sea including Beris, Ramin, Pozm, Konarak and Jask from March 2017 to March 2018. The biometric analysis was performed on more than twenty-six thousand fish. Population dynamic parameters were calculated including infinite length ($L\infty$=171 cm), growth coefficient (K=0.54 (yr-1)), growth performance index (Φ'=4.19), natural mortality (M= 0.71(yr-1)), fishing mortality (F=1.57 (yr-1)), total mortality (Z=2.28±0.19 (yr-1)), exploitation coefficient (E=0.68 (yr-1)) and initial condition parameter (-0.18 yr-1). Relative production per recruitment, relative biomass per recruitment and exploitation rate of this species were Y'/ Rp = 0.04, B'/ Rp=0.23(yr-1) and U=0.62 (yr-1), respectively. The Pobj value is <1, Popt and Pmega>0, and F/Fmsy>1. The results indicated that regarding length frequencies of this species in the northern part of the Oman Sea, yellowfin tuna stock has good conditions, but overfishing of this species is happening, now. Therefore, specific measures should be taken to reduce catch and fishing effort.

Keywords: *Thunnus albacares*, Length frequency, Population dynamic parameters, Oman Sea

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Introduction

Global total capture fisheries production in 2016 was about 91 million tons, 87% of which were in seawater (79.3 million tons) and 13% in inland waters (11.6 million tons). Global database of marine fisheries showed that catches declined by about 2 million tons compared to 2015 (81.2 million tons). The catch in the Indian Ocean was over 11 million tons and the western part of the ocean had about 5 million tons of this catch (FAO, 2018). The ratio of stocks with Biologically Sustainable Levels (BSLs) to stocks with Biologically Unsustainable Levels (BULs) is one of the most important issues in sustainable exploitation and development of the seas. Stocks with Biologically Unsustainable Levels (BULs) were about 10 percent in 1974 and about 33 percent in 2016. In 1974, stocks with Biologically Sustainable Levels (BSLs) were 90% and in 2016 reached about 67%. The largest ratios of Biologically Unsustainable Levels are found in the Mediterranean, Black Sea, and Southeast Pacific Ocean as well as Southwest Atlantic Ocean. Estimates show that 43 percent of tuna stocks are considered Biologically Unsustainable, whereas 57 percent of tuna stocks are considered Biologically Sustainable. The group of tuna (tuna, seer fish, and billfish) makes up about 9% of global catch (FAO, 2018).

Tuna belongs to the order of Perciformes and the family of Scombridae (Jamili et al., 2019). This family consists of 52 species and 15 genera (Collette and Nauen, 1983; Froese and Pauly, 2018). The genus *Thunnus* has 8 species, two of which are found in the Persian Gulf and the Oman Sea (Kaymaram *et al*., 2009). Yellowfin tuna is epiglacial migratory species in tropical and subtropical regions across the oceans (Pacific, Atlas and India) can be seen. This species is found up to 250 meters (usually up to 100 meters) and adults tend to be deeper and offshore (as opposed to immature). Their preferred temperatures ranged from 15-31°C with a maximum length of 239 cm (usually about 150 cm), a maximum weight of 200 kg and a maximum age of 9 years (Collette and Nauen, 1983; Froese and Pauly, 2018). This species is one of the important tuna fisheries throughout tropical and subtropical seas and also it is the 8th largest species in the world fisheries production (near 1.6 million tons in 2016) and the country with the largest catches is Indonesia (FAO, 2018).

Various studies have been done on this species in the world (John and Reddy, 1989; Chantawong, 1998; Kaymaram *et al*., 2000; Tantivala, 2000; Somvanshi *et al*., 2003; Prathibha *et al*., 2012; Ramalingam *et al*., 2012; Kaymaram *et al*., 2014; Nurdin *et al*., 2016; Haruna *et al*., 2018). This study investigated the demographic characteristics of *T. albacares* in the northern Oman Sea. The purpose of this study was to provide basic information for identifying the stock status and principally its exploitation. Another aim of this investigation was to better understand the biological and population characteristics of the species that its catch has been grown rapidly in recent years.

Materials and methods

Based on the commercial fish catch statistics in the northern Oman Sea, five landing areas were selected for sampling of *T. albacares* in the ports of Beris (61˚ 10´E, 28˚ 82´N), Ramin (60˚ 45´E, 25˚ 15´N), Pozm (60˚ 28´E, 25˚ 14´N), Konarak (60˚ 28´E, 25˚ 60´N) and Jask (57˚ 77´E, 25˚ 64´N) (Fig. 1). Landings Data (tons) of this species was collected by the Iranian Fisheries Organization, IFO (from 1997 to 2018) (IFO, 2019).

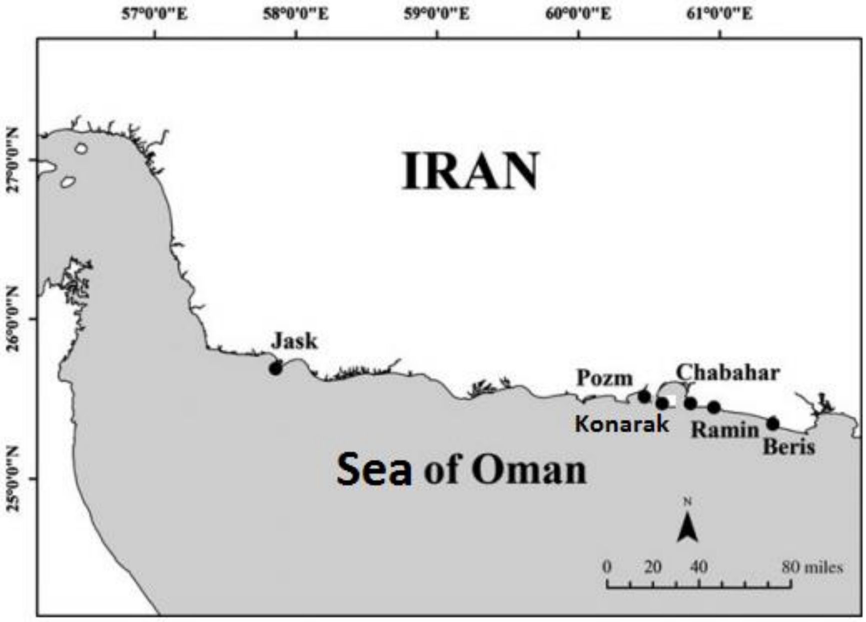

Figure 1: Location of *T. albacares* sampling stations in the northern Oman Sea.

Length frequency distribution

Sampling was carried out monthly from the fish landing area of Beris, Ramin, Pozm, Konarak and Jask. Random sampling from commercial catches landed in these ports and according to the schedule from March 2017 to March 2018 performed sampling. Biometric analysis (length measurement) was performed on more than twenty-six thousand fish. Fork length was measured by biometric ruler with 1 cm precision.

Growth parameters

The estimation of L∞ was obtained using the Froese and Binohlan equation, logLoo=0.044+0.9841 * log (Lmax) (Froese and Binohlan, 2000). Growth rate was obtained by applying the ELEFAN (Electronic Length Frequency Analysis) method (optimization model), RStudio (1.1.46 Version) software, and TropFishR package (Mildenberger *et al*., 2017). The optimum value of t_0 was calculated by the experimental formula of Pauly equation (Froese and Binohlan, 2000):

$(\text{Log } (-t_0) = -0.3922 - 0.2752 \text{ Log } L\infty - 1.038 \text{ Log } K)$

Comparison of growth indices such as infinite length ($L\infty$) and growth factor (K) was performed using the equation of:

$\Phi ' = \text{Log (K)} + 2 \text{ Log } (L\infty)$.

Mortality estimate

Natural mortality (M) was calculated based on the Pauly equation (Sparre and Venema, 1998):

$\text{Ln (M)} = -0.0152 - 0.297 \text{ Ln } (L\infty) + 0.654 \text{ Ln (k)} + 0.642 \text{ Ln (T)}$

In this equation, M is the annual natural mortality coefficient, $L\infty$ is the infinite length of the fish (cm), K is the growth curve parameter of von Bertalanffy growth equation and T is the mean environmental temperature (Sparre and Venema, 1998). The mean annual temperature of the surface water of this area was set at 26°C (Kaymaram *et al.*, 2009). Total mortality (Z) was calculated based on the length - converted catch curve data. The fishing mortality was estimated using the relationship:

$(F = Z - M)$

Z is the total mortality, F is fishing mortality and M is natural mortality.

The exploitation rate (E), which is the ratio of fishing mortality to total mortality, was calculated with the relationship of E = F / Z (Sparre and Venema, 1998).

Yield per recruit and biomass per recruit

The relative yield per recruitment was determined against the fishing mortality coefficient or exploitation rate. In this equation, E is the exploitation coefficient, U the exploitation rate, M is the natural mortality coefficient, F is the fishing mortality coefficient and L_c is the same as L_{c50} (Gayanilo and Pauly, 2003). In addition, the relative biomass per recruitment (B'/ Rp) was calculated using the following equation.

$Y'/R = EU^{M/K} (-3U/(1+m) + 3U^2/(1+2m) + U^3/(1+3m)$

$U = 1-(L_C/L_\infty)$; $M = (1-E)/(M/K) = (K/Z)$;

$E = F/Z$

$B'/R = Y'/R/F$

Length-based reference point

length-based reference point is described below: percentage of mature fish in the catch (Pmat), percentage of fish caught at the optimum length for harvest (Popt), and percentage of mega-spawners (length between 1.1 *L*opt and Lmax on the catch length composition) in the catch (Pmega); collectively referred to as Pobj value (Cope and Punt, 2009). Length at maturity (*L*mat) of this species was estimated 76 cm in the northern Oman Sea (Kaymaram *et al.*, 2009). Values for optimal fishing length (*L*opt*)* are calculated as follows (Froese and Binohlan, 2000):

$Lopt = L_\infty * (3/3+M/K)$.

Fish stock condition

Fish stock condition was evaluated based on this equation, {(Heaviness×value/ full value)}×100%; where the full value is 55. Each indicator assigned different heaviness according to its urgency; each indicator is divided into sub-indicators with different values. Furthermore, multiplication of indicator heaviness and value of the indicator is obtained. The stock condition used references, such as, Stock condition ≥85–100% - very good; Stock condition <65–85% - good; Stock condition <65% - low (Mallawa *et al.,* 2015; Haruna *et al.*, 2018) (Table 1).

Table 1: Survey of stock condition based on its population indices

Indicator	Range	Heaviness	Value	Heaviness × value
Size Structure	Small fish Small - medium fish Medium - Large fish	2	1 3 5	10
Number of age groups	Less than three Three to five More than five	2	1 3 5	10
The rate of fishing mortality	More than two Between one and two Less than one	2	1 3 5	10
The rate of exploitation	More than 1 Between 1 and 0.5 Less than 0.5	1	1 3 5	5
The rate of population growth	Less than 0.5 per year Between 0.5 - 0.75 per year More than 0.75 per year	1	1 3 5	5
The percentage of eligible catch size	Less than 30 % Between 30 % and 50 % More than 50 %	2	1 3 5	10
Yield per Recruitment	Y/R now> Y/R optimal Y/R now = Y/R optimal Y/R now< Y/R optimal	1	1 3 5	5
	-	-	-	55

The exploitation rate (U) was estimated using the equation given by Beverton and Holt (1957) as $U=F(1-e^{-z})/Z$. Annual catch (Y) this species is near 53000 tones (2018 year) collected from the Department of Fisheries (IFO, 2019). Then by using the values of U, virgin biomass ($B_{\infty}=Y/U$) and average standing stock (B=Y/F) were determined (Pillai *et al*., 2002). Data analysis was performed using Excel program, FiSAT II software and R Studio software (1.1.46) as well as the TropFishR package.

Results

The amount of total catch and catches of large pelagic fish in the northern Oman Sea has been increasing in recent years. The amount of *T. albacares* catch has increased from about 17 thousand tons in 1997 to about 52 thousand tons in 2018 and during the past decades, the catch rate of this species has been increased significantly (p<0.05). The catch ratio (%) of this species to the total catch as well as to large pelagic fish catch in this area changed from about 59% and 41% in 1997 to 23% and 16% in 2018, respectively (Fig. 2).

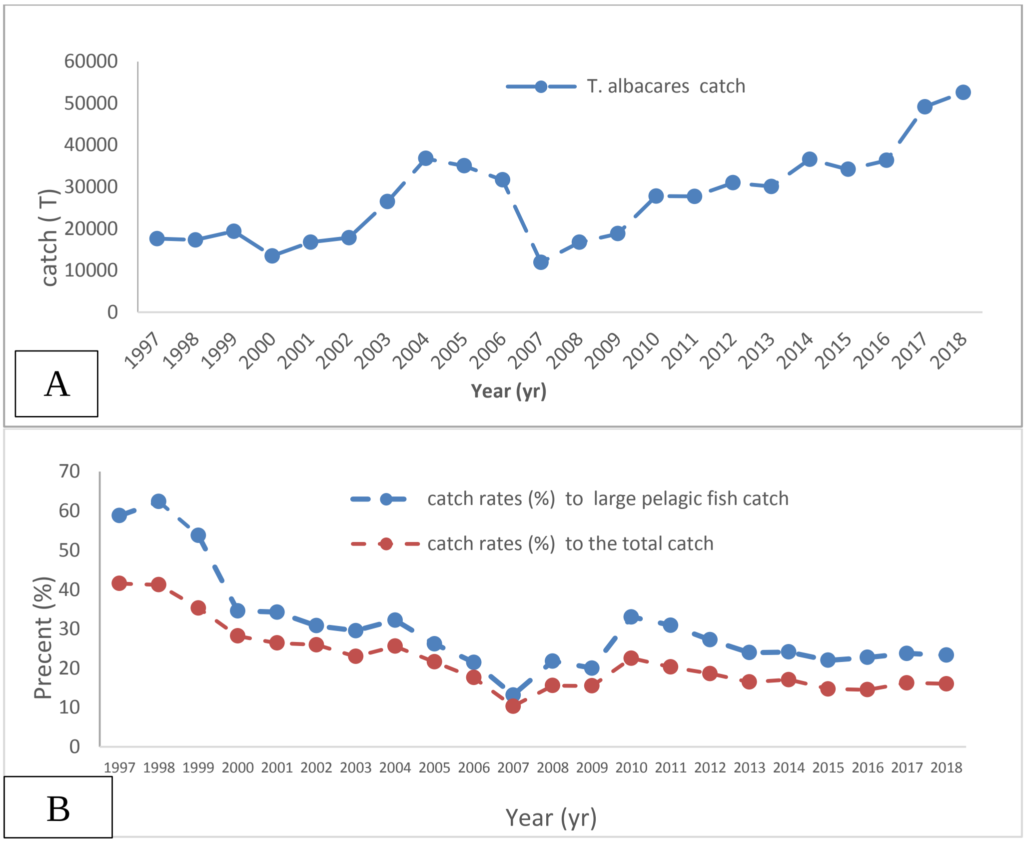

Figure 2: The *T. albacares* catch (A) and this species catch ratio (%) to total and to large pelagic fish catch (B) in the northern Oman Sea.

Length frequency analysis was performed on 26163 fish. The minimum fish length was 48 cm and maximum fish length was 171 cm and the average length (± SD) was 84±15 cm of this study. Fish length data were categorized into 7 cm groups and the highest frequency (5430 fish) and percentage frequency (near 20%) were observed in fish with 69 to 76 cm length (Fig. 3).

Population dynamics parameters of yellowfin tuna were as follows; infinite length 171cm, growth coefficient 0.54 (yr^{-1}), time zero -0.18 yr., growth performance index (Φ '=4.19) and natural mortality 0.71 (yr^{-1}), fishing mortality 1.57 (yr^{-1}), total mortality 2.28 (yr^{-1}) (Fig. 4). The von Bertalanffy equation for this species was calculated as follows:

$$L_t = 171(1 - \exp(-0.54\,(t+0.18)))$$

In this equation L_t is the fork length of the fish (cm) at a given age and the t is the age of the fish (year).

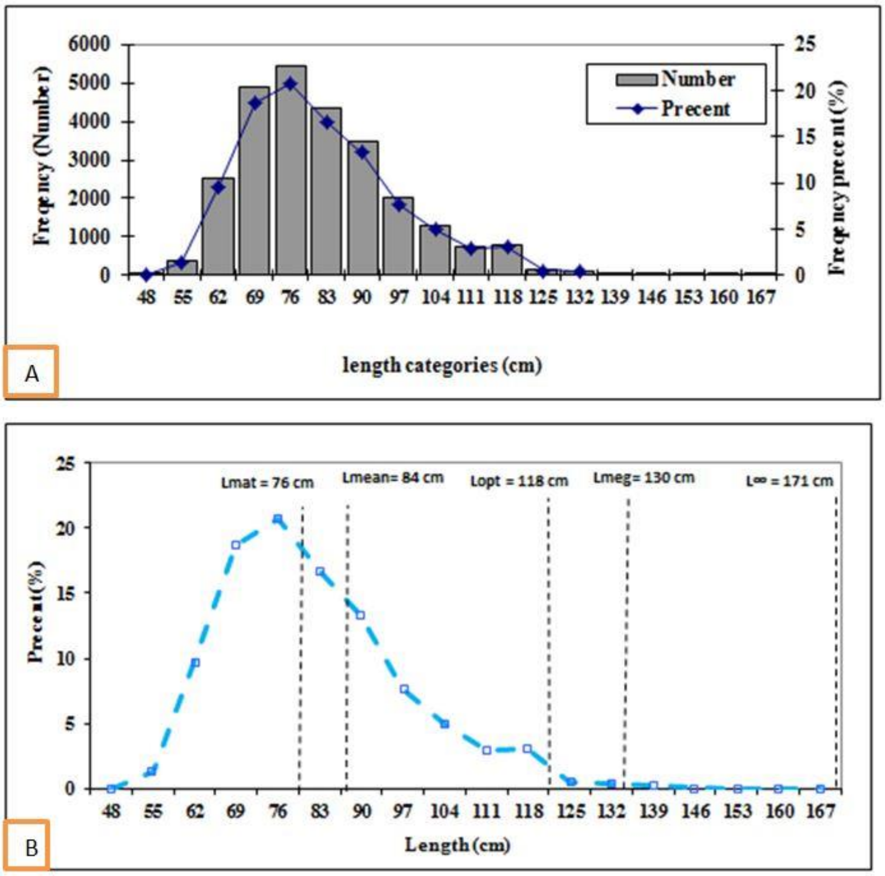

Figure 3: Length and percentage frequency in different length categories (A) and length-based reference point (B) of *T. albacares.*

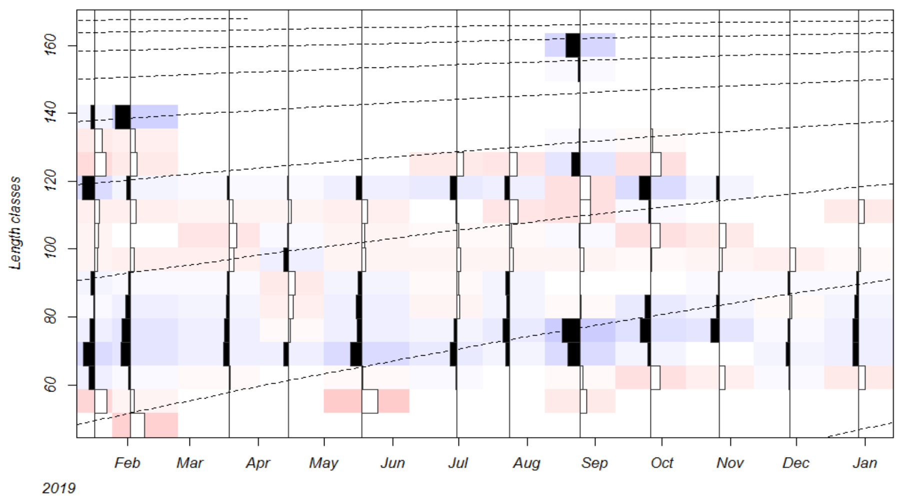

Figure 4: Growth curve derived from length frequency data of *T. albacares* in the northern Oman Sea.

Using the von Bertalanffy equation, fish lengths at different ages can be calculated.

L_c or L_{c50} is equal to the length at which the probability of catching fish at this length is 50% (61 cm in the present study). Relative production per recruitment and relative biomass per recruitment were $Y'/R_p=0.04$ and $B'/R_p=0.23(yr^{-1})$, respectively. Overall estimates indicated that the exploitation rate of U = 0.62 (yr^{-1}) and the fishing mortality at maximum sustainable yield, Fmsy was estimated 0.6 (yr^{-1}). Length-based reference point is percentage of mature fish in the catch (Lmat=76 cm, Pmat=0.49), percentage of fish caught at the optimum length for harvest (Lopt=118 cm, Popt=0.18), and percentage of mega-spawners in the catch (Lmega=130 cm, Pmega=0.006) and Pobj = 0.69, respectively (Fig. 5).

A

B

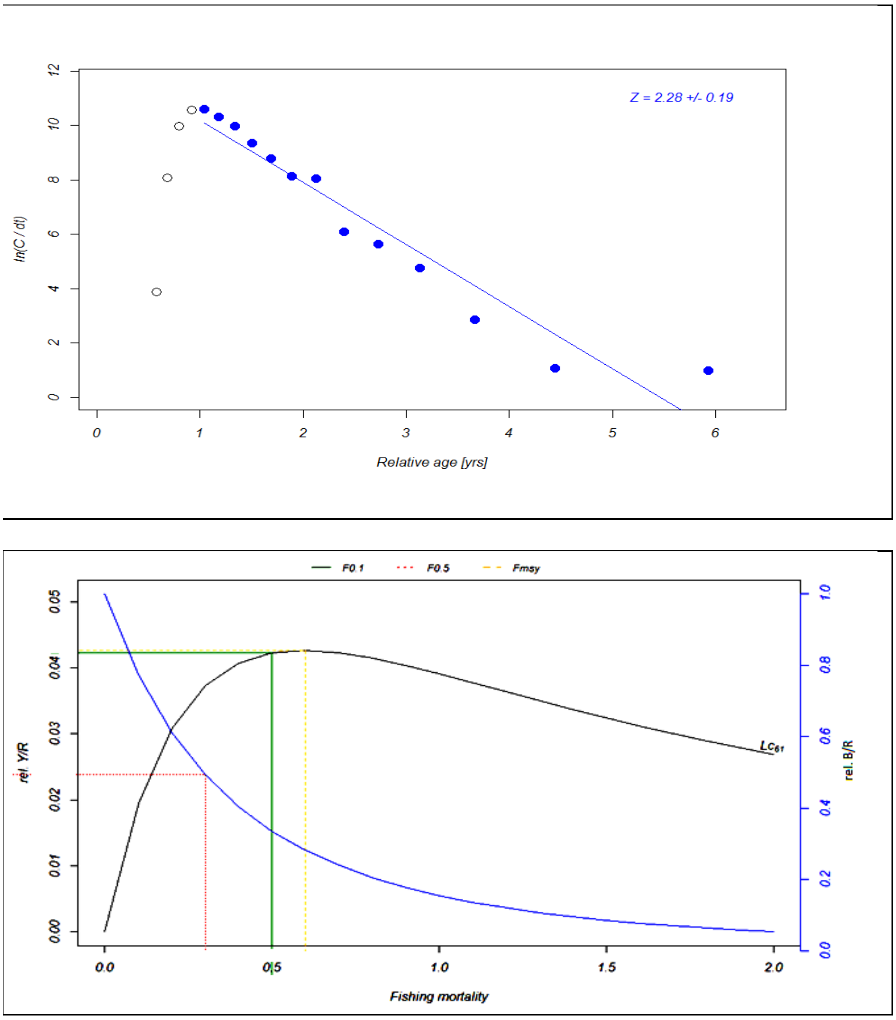

Figure 5: Total mortality curve (A) and fishing mortality, Y' / R and B' / R (B) of *T. albacares* in the northern Oman Sea.

The appraisal of stock condition

The appraisal of stock condition indicator that was acquired from several population parameters can be seen in Table 2. The results show that *T. albacares* resources remain in low condition. However, there are several criteria, such as size structure, number of age groups, and mortality rates below the optimum average, while other criteria are above the optimum average.

Table 2: The appraisal of the *T. albacares* stock condition in the Oman Sea

Indicator	Heaviness	Value	Heaviness × value
The size structure (large)	2	5	10
Number of age groups (>five age groups)	2	5	10
The rate of catch mortality (F>1.0)	2	3	6
The rate of exploitation (E > 0.5 -< 1.0)	1	3	3
The rate of population growth (K> 0.5/year)	1	3	3
The percentage of eligible catch size (30 -<50%)	2	3	6
Yield per recruitment (Y/R now <Y/R optimum)	1	5	5
Σ Heaviness x value	-	-	43
Percentage (%)	-	-	78
Stock condition	-	-	good

The index values of fish stock condition for calculation were as follows; length frequency ($2_\times5$), number of age groups ($2_\times5$), fishing mortality ($2_\times3$), exploitation rate ($1_\times3$), growth rate ($1_\times3$), acceptable biological catch ($2_\times3$), maximum recruitment ($1_\times5$). As a result, the value of this index was 78% ($43/55_\times100$). Also, the value of virgin biomass (Bv=B0) and average standing stock (B) were near 85000 (t) and 33000 (t), respectively.

Discussion

T. albacares is one of the most economically valuable fish in the south of Iran; its catch has been increased in recent years in the northern Oman Sea. Total catch of yellowfin tuna was more than 58,000 tons in 2019 (IFO, 2020). Comparison of the biological indices of this species (the present study) with other studies in different parts of the world was presented in Table 3. It seems that the infinite length of Yellowfin tuna in the Oman Sea region is less than the infinite length of this species in the east coast of India, Indonesia and the Arabian Sea regions. The growth rate of this species in the Oman Sea is more than the other areas in the Indian Ocean. The $L\infty$ obtained in this area for the Yellowfin tuna are less than the estimate given by Kaymaram *et al*. (2000) and Kaymaram *et al*. (2014) and the K estimate was higher than the estimate given by Kaymaram *et al*. (2000) and Kaymaram *et al*. (2014) that may be due to sampling method.

Table 3: Comparison of population dynamic parameters of *T. albacares* with other studies in the Indian Ocean.

References	Region	L∞ (cm)	K (yr^{-1})	t_o (yr^{-1})	Φ'	tmax (yr)	M (yr^{-1})	F (yr^{-1})	Z (yr^{-1})	E
Maldeniya and Joseph (1986)	Sri Lanka	178	0.47	-0.2	-	6.3	-	-	-	-
Anonymous (1987)	Sumatra	175	0.5	-	-	-	-	-	-	-
John and Reddy (1989)	West coast of India	175	0.29	-	-	10.3	0.74	-	-	-
Chantawong, (1998)	East coast of India	194	0.66	-0.27	-	11.3	-	-	-	-
Tantivala (2000)	East coast of India	185	0.34	-0.003	-	-	-	-	-	-
Kaymaram *et al.* (2000)	Oman Sea (Iran)	189	0.42	-0.23	-	-	0.6	-	-	-
Somvanshi *et al.* (2003)	The Arabian Sea	193	0.2	-	-	-	-	-	-	-
Ramalingam *et al.* (2012)	Nicobar Sea (India)	173	0.39	-0.09	-	7.6	0.51	-	-	-
Prathibha *et al.* (2012)	East coast of India	197	0.3	-0.11	-	10.1	0.48	0.23	0.71	0.32
Kaymaram *et al.* (2014)	Oman Sea (Iran)	183	0.45	-0.18	4.21	6.5	0.48	1.56	2.04	0.76
Nurdin *et al.*, 2016	Indonesia (Palabuhanratu waters, west Java)	178	0.47	-	4.17	-	0.61	0.66	1.27	0.48
Haruna *et al.*, 2018	Indonesia (Banda Sea)	215	0.31	-0.31	4.21	9.37	0.49	0.98	1.47	0.67
Present study,	Oman Sea (Iran)	171	0.54	-0.18	4.19	5.38	0.71	1.57	2.28	0.68

Differences in the amounts of the infinite length and growth rate are influenced by the ecological differences of each region (King, 2007). In general, the difference in the infinite length and growth rate from one region to another can be due to the quantity and quality of food and climatic conditions (Bartulovic *et al.,* 2004). Various factors can also affect fish growth including age, sex, season, year, type of feeding, physiological conditions, differences in food availability and reproductive period (Lalèyè, 2006).

The Growth performance index (Φ′) was found to be 2.19 that is consistent with the study by Kaymaram *et al.* (2014) (Table 3). Differences in ecological conditions and latitude changes can affect the values of infinite length and growth rate. These variations include varying values of Φ' and even in one region at different time periods may have varying values due to changing environmental conditions (King, 2007).

The fishing mortality rate of this species was higher than that of natural mortality. The ratio of fishing mortality to F at maximum sustainable yield (F/ FMSY) was more than one. If the value of F/ FMSY is more than one, it indicates that there is overfishing (Arrizabalaga *et al*., 2012). In addition, the ratio of average standing stock to virgin biomass (B/ B∞) was near 0.39. The value of B/ Boo is under than 0.4, which indicates the overfished status (Arrizabalaga *et al*., 2012). The exploitation coefficient and the exploitation rate were greater than 0.5 (indicating that the amount of capture fisheries was more than optimum level). These indices (exploitation coefficient and exploitation rate) in the population should not be greater than 0.5 or the fishing mortality should not exceed natural mortality because they indicate overfishing (Sparre and Venema, 1998; King, 2007).

According to the different studies in the Indian Ocean, the amounts of natural mortality, fishing mortality, total mortality and exploitation coefficient have been reported in the range of 0.4 to 0.7 per year, 0.2 to 1.5 per year, 0.7 to 2 per year, and 0.3 to 0.7 per year, respectively (John and Reddy, 1989; Kaymaram *et al*., 2000; Prathibha *et al*., 2012; Ramalingam *et al*., 2012; Kaymaram *et al*., 2014; Nurdin *et al*., 2016; Haruna *et al*., 2018). This study confirms to previous studies on this species in the Oman Sea (Kaymaram *et al*., 2014). The yellowfin tuna stock in the Indian Ocean has been reported overfishing and overfished with Maximum Sustainable Yield (MSY), 403 (339-436) thousand tons (IOTC, 2019). The most important factors affecting the pressure on fish stocks are the amount of catch and environmental factors that affect survival and access to the fishery resources (Mateus and Estupinan, 2002). Based on the results, the maximum life span of *T. albacares* was about five years (based on formula $t_{max} = t_0+3/K$ (Froese and Pauly, 2018)). Based on the criteria defined by the American Fisheries Society (Cheung *et al.*, 2004) and comparing the results obtained in the present investigation with these indices, the extinction vulnerability of this species was estimated to be high (Table 3).

T. albacares condition were 78% based on the formula and fish stock conditions are (more than 65% indicates good fish stock conditions) (Mallawa *et al.*, 2015; Haruna *et al.*, 2018). The Pobj value is<1, and Popt and Pmega>0, that show considered undesirable. If the Pobj value<1, this is indicative of selectivity patterns that do not follow sustainability recommendations (Cope and Punt, 2009). Also, Length frequency of this species showed near 50% of the length frequencies were below length at maturity (Lmat) and this ratio can be alarming.

The results indicated that regarding length frequencies of this species in the northern part of the Oman Sea, yellowfin tuna stock has good conditions, but overfishing of this species is happening, now. Therefore, specific measures should be taken to reduce catch and fishing effort.

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References

Anonymous, 1987. Tuna in the Andaman Sea, Bay of Bengal Programme, Report No. 40, 11P.

Arrizabalaga, H., Murua, M. and Majkowski, J., 2012. Global status of tuna stocks: summary sheets. *Revista de Investigación Marina, AZTI-Tecnalia*, 19(**8**), 645-676.

Bartulovic, V., Glamuzina, B., Conides, A., Dulcic, J., Lucic, D., Njire, J. and Kozul, V. 2004. Age, Growth, Mortality and Sex Ratio of Sand Smelt, *Atherinaboyeri*, Risso, 1810 (Pisces: *Atherinidae*) in the Estuary of the Mala Neretva River (Middle-Eastern Adriatic, Croatia). *Journal of Applied Ichthyology*, 20, 427-430. DOI:10.1111/j.1439-0426.2004.00560.x

Beverton, R.J.H. and Holt, S.J., 1957. On the Dynamics of Exploited Fish Populations. Ministry of Agriculture, Fisheries and food, London (republished by champan and hall,1993).

Chantawong, P., 1998. Tuna fisheries in the East Indian Ocean, 1993-1998. Working paper TWS/98/1/9 presented to 7th Expert Consultation on Indian Ocean Tunas, 9-14 November, Victoria, Seychelles.

Cheung, W., Pitcher, T. and Pauly, D., 2004. A fuzzy logic expert system to estimate intrinsic extinction vulnerabilities of marine fishes to fishing. Biological conservation 124(97-111).

Collette, B.B. and Nauen, C.E., 1983. FAO species catalogue. Vol. 2. Scombrids of the world. An annotated and illustrated catalogue of tuna, mackerel’s bonitos and related species known to date. *FAO Fisheries Synopsis*, 125, 2, 137P.

Cope, J.M. and Punt, A.E., 2009. Length-Based Reference Points for Data-Limited Situations: Applications and Restrictions. *Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science*, 1, 169–186. DOI: 10.1577/C08-025.1.

FAO, 2018. The State of World Fisheries and Aquaculture 2018 - Meeting the sustainable development goals. Rome. Licenses: CC BY-NC-SA 3.0 IGO. 227P.

Froese, R. and Binohlan, C., 2000. Empirical relationships to estimate asymptotic length, length at first maturity and length at maximum yield per recruit in fishes, with a simple method to evaluate length frequency data. *Journal of Fish Biology***,** 56, 758-773.DOI: 10.1111/j.1095-8649.2000.tb00870.x

Froese, R. and Pauly, D., 2018. Fish Base World Wide Web electronic publication http://www.fishbase.org; (26,06.2018).

Gayanilo, F.C. and Pauly, D., 2003. The FAO-ICLARM Stock Assessment Tool (FiSAT) users guide. Rome. ITALY.

Haruna, A., Mallawa, A., Musbir, M. and Zainuddin, M., 2018. Population dynamic indicator of the yellowfin tuna *Thunnus albacares* and its stock condition in the Banda Sea, Indonesia. *AACL Bioflux*, 11(**4**), 1323-1333.

IFO, 2019. Iran Fisheries Organization (IFO). Bureau of Statistics; Yearbook of Fisheries Statistics. 25P.

IOTC, 2019. Review of the statistical data and fishery trends for tropical tunas. IOTC–2019–WPTT21–08_Rev1.

Jamili, S., Sadeghi, H., Rezayat, M., Attar, H., Kaymaram, F., 2019. Extraction and evaluation of gelatin from yellow fin tuna (*Thunnus albacares*) skin and prospect as an alternative to mammalian gelatin. *Iranian Journal of Fisheries Sciences***.** 18 (4), 903-914. DOI: 10.22092/ijfs.2019.119072

John, M.E. and Reddy, K.S.N., 1989. Some considerations on the population dynamics of yellowfin tuna, *Thunnus albacares* (Bonnaterre) in Indian Seas. Studies on fish stock assessment in Indian waters. *Foreign Service Institute Special Publication*, 2, 33- 54.

Kaymaram, F., Emadi, H. and Kiabi, B. 2000. 2nd IOTC proceedings, Victoria, 23-27 September, Seychelles, 283-285.

Kaymaram, F. Hosseini, A. Darvishi, M. and Talebzadeh, A., 2009. Report on the Study of Population Changes of large pelagic fish (yellowfin tuna, skipjack tuna, longtail tuna, narrow-barred Spanish mackerel, etc.) for optimal harvesting of resources in the Persian Gulf and Oman Sea. Iranian Fisheries Science and Research Institute in collaboration with Chabahar Offshore Fisheries Research Center and Persian Gulf and Oman Sea Ecological Research Institute, 126P.

Kaymaram, F., Hosseini, S.A. and Darvishi, M., 2014. Estimates of Length-Based Population Parameters of Yellowfin Tuna (*Thunnus albacares*) in the Oman Sea. *Turkish Journal of Fisheries and Aquatic Sciences*, 14(**1**), 101-111. DOI: 10.4194/1303-2712-v14_1_12.

King, M.G., 2007. Fisheries biology assessment and management. Second edition published by Blackwell Publishing Ltd., ISBN. 978-1-4051-5831-2, pp. 189-194.

Lalèyè, P.A., 2006. Length-weight and length-length relationships of fish from the Ouémé River in Bénin (West Africa). *Journal of Applied Ichthyology*, 22, 502-510.

Maldeniya, R. and Joseph, L., 1986. On the distribution and biology of yellowfin tuna from the western and southern coastal waters of Sri Lanka. Collective Volume of working documents presented at the Expert Consultation on Stock Assessment of Tunas in the Indian Ocean, held in Colombo, Sri Lanka: 28Nov.-2 Dec. 1985. pp. 51-61.

Mallawa, A., Amir, Musbir, F. and Susianti W., 2015. Assessment of *Katsuwonus pelamis* conditions in

Flores Sea waters, South Sulawesi. Proceedings of the National Symposium on Marine and Fisheries II, pp. 299-307, Hasanuddin University Press, 513P. [In Indonesian].

Mateus, A. and Estupina, B., 2002. Fish stock assessment of Piraputanga (Brycon microlepis) in the Cuiaba Basin. *Brazilian Journal of Biology*, 62(**1**): 165-170. DOI: 10.1590/S1519-69842002000100018.

Mildenberger, T.K., Taylor, M.H. and Wolff, M., 2017. TropFishR: An R package for fisheries analysis with length-frequency data. *Methods in Ecology and Evolution*, 8, 1520–1527.DOI:10.1111/2041-210X.12791.

Nurdin, E., Sondita, M.F.A., Yusfiandayani, R. and Baskoro, M.S., 2016. Growth and mortality parameters of yellowfin tuna (*Thunnus albacares*) in Palabuhanratu waters, west Java (eastern Indian Ocean). *AACL Bioflux*, 9(**3**), 741-747.

Pillai, P.P., Pillai, N.G., Muthiah, C., Yohannan. T.M., Mohamad kasim, H., Gopakumar, G., SaidKoya, K.P., Manojkumar, M., Sivads, M., Nasser, A.K. V., Ganga, U., Dhokia, H.K., Kemparaju, S., Bhaskaran, M.N.K., Elayathu, M.N.K., Balasubramaniam, T., Manimaran, C., Kunhikoya, V.A. and Ajith Kumar, T.T., 2002. Stock assessment of coastal tuna in the Indian seas. In: N.G.K. Pillai, N.G. Menon, P.P. Pillai, and U. Ganga, (Eds.) Management Scombroids Fisheries, Central Marine Fishery Research Institute, Kochin. pp. 240-250.

Prathibha, R., Syda Rao, G. and Rammohan, K., 2012. Age, growth and population structure of the yellowfin tuna *Thunnus albacares* (Bonnaterre, 1788) exploited along the east coast of India. *Indian Journal of Fisheries*, 59(**1**), 1-6.

Ramalingam, A.B., Kar, L., Govindaraj, K. and Prasad, G.V.A., 2012. Study of the growth and population parameters of yellowfin tuna (*Thunnus albacares*) in the Andaman and Nicobar waters based on the length frequency data. Report of14th IOTC proceedings. 24– 29 October. Mauritius. 17P.

Somvanshi, V.S., Bhargava, A.K., Gulati, D.K., Varghese, S. and Varghese, S.P., 2003. Growth parameters estimated for yellowfin tuna occurring in the Indian EEZ. 6th IOTC proceedings. Victoria, 3-12 June, Seychelles, 191-193.

Sparre, P. and Venema, S.C., 1998. Introduction to tropical fish stock assessment, FAO Fisheries technical paper, Roma, 450P.

Tantivala, C., 2000. Some biological study of yellowfin tuna (*Thunnus albacares*) and bigeye tuna (*Thunnus Obesus*) in the eastern Indian Ocean. 2nd IOTC proceedings. Victoria, 23-27 September, Seychelles. pp. 436-440.