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ORIGINAL ARTICLE

Changes in length-base demographic parameters of Yellowfin tuna (*Thunnus albacares* Bonnaterre, 1788) during two periods of time in the northern waters of the Oman Sea

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Abstract
This research looked at the basic information about *Thunnus albacares* found in the northern part of Oman's Sea, and give useful information on how correctly manage of this resource. During the years of this study (1992 and 2022), over 6000 fish were measured and the average length (range) of Yellowfin tuna fish in 1992 and 2022 was 93±26 (21-157) cm and 77±18 (24-175) cm, respectively. The average weight (range) of this species was 9127±1251 (3500-55000) grams in 1992 and 10639±1450 (1100-85000) grams in 2022. The relationship between fork length and total body weight for the year 1992, $W=0.014\times L^{2.51}$ (R^2=0.83, N=750) and the year 2022, $W=0.019\times L^{2.46}$ (R^2=0.89, N=703) was obtained. Vonbertalanffy equation for this species in the northern waters of the Oman Sea (Iran) was calculated in 1992 and 2022 respectively as: $L_t= 182$ (1-exp (-0.39 (t +0.25)) and $L_t= 177$(1-exp (-0.55 (t +0.18))). The ratio of spawning potential based on length (LBSPR) in 1992 and 2022 were 0.22 (0.20-0.25) and 0.10 (0.09-0.12), respectively. Based on ratio of $P_{mega} < 0.1$, $L_{mean}/ L_{opt} <1$ and $L_{mean} /L_{F=M} <1$ show considered undesirable. Decrease of the average length, LBSPR index and increase of fishing and total mortality can be a reason for overfishing. The present study showed that the Yellowfin tuna stock has reached 'overfished' status. The findings of this study can assist management and sustainable harvest of this species stocks.

Keywords: Overfishing, Spawning potential ratio, Vonbertalanffy equation, Sustainable harvest.

INTRODUCTION

Only a small percentage of fisheries in the world (about 11%) are evaluated using advanced models to better understand their status and sustainability (FAO 2019). Due to more and more fishing effort around the world, with changes in the ocean's climate and environment, the availability of fish and these resources fluctuated and their harvest has been changing year to year (Shi et al. 2022).

Out of all the animal resources we use, fisheries resources are the biggest. The size, behavior, and ability of fish populations to recover from changes create difficulties in their assessment and management. The fishery populations are special for at least three reasons (Vivekanandan 2005). (i) Many species can spread out spatial dissemination. (ii) Numerous species show wide temporal variations in abundance. (iii) Since the resources cannot be seen visually and function of the resources is a challenge (Vivekanandan 2005). Stock assessment is the method of gathering and reviewing data on fish populations to determine changes in the abundance of fishery stocks. It also tries to predict what might happen to the fish population in the future (Vivekanandan, 2005).

Tuna is a type of fish that belongs to the Perciformes group and the Scombridae family. This family has 54 different kinds of creatures and 15 groups. The *Thunnus* genus has 8 species that some of them live in the Persian Gulf and the Oman Sea (Froese & Pauly 2022). Yellowfin tuna is a fish that moves around in warm areas of the oceans like the Pacific, Atlantic and Indian oceans. This kind of animal ordinarily found within the water up to 250 meters deep, but usually only up to 100 meters. The older ones usually swim farther out to sea than the younger ones. Their favorite temperature is between 15 to 31 degrees Celsius. They

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Fig.1. Location of *T. albacares* sampling stations in the northern waters of the Oman Sea, Iran.

can grow up to 239 cm (but usually around 150 cm), and can weigh up to 200 kg. They usually live up to 9 years old (Collette & Nauen, 1983). This type of fish called tuna is very important for fishing in warm ocean areas. It is the ۵th biggest kind of fish caught for food in the world, near 1. 6 million tons caught in 2020 (two percent of the world's total marine catch in 2020). Indonesia has the largest catch of this species (FAO 2022).

Many researchers have studied this species around 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; Hashemi et al. 2020; Hashemi et al. 2022). This research looked at the basic information about Yellowfin tuna found in the northern part of Oman's Sea. This study aimed to give useful information on how correctly manage of this resource. This investigation was done to learn more about a type of animal that has been caught and to understand how it changes and grows.

MATERIALS AND METHODS

Five places were chosen to study *T. albacares,* because a lot of this fish catch in these areas of the northern waters of the Oman Sea. There are 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). The Iranian Fisheries Organization collected information about how much of this type of fish was caught each year from 1997 to 2022. This is called the landings data. The information was published in 2023 (IFO 2023).

Length Frequency Distribution: Fish were collected every month from fish landing local of Beris, Ramin, Pozm, Konarak, and Jask. From the fish caught in these ports just 1992 and 2022, samples were taken randomly to study them. Fish length measured over 6000 samples (3700 samples in 1992 and 2700 samples in 2022) using biometric analysis.

Biometry: Biometric measurements (Fork-length and total weight) were performed. Fork length was measured using a ruler with 1 cm accuracy and wet weight by the close to 10g. The Equation (1) was used to calculate relationship between the fork length and weight, with, *Wi* is the total weight (g), *Li*, the fork length (mm), a is regression constant (intercept) and b is the regression slope (fish growth rate) (Biswas 1993).

$$Wi = a \times Li^{b} \quad (1)$$

In order to verify if calculated b was significantly different from 3, the t-test was employed using the statistic: t_s= (b-3) /Sb, where Sb is the standard error of the slope (Zar 1996).

Growth Studies: The estimation of L∞ was used by math equation that called the Froese and Binohlan equation, logL∞= 0.044+0.9841×log (Lmax) (Froese & Binohlan 2000). The growth rate evaluated by using a computer program called Electronic Length Frequency Analysis (ELEFAN) method with optimization model, RStudio (1.1.46 Version) software, and TropFishR package (Mildenberger et al. 2017).

The best value of t_0 calculated by special equation called Pauly's equation, ($\text{Log}(-t_0) = -0.3922 - 0.2752\ \text{Log}L\infty - 1.038\ \text{Log}\ K$) (Froese & Binohlan 2000). The fish grow compared by measuring two factors, their maximum length ($L\infty$) and growth parameter (K), which the formula called as: $\Phi' = \text{Log}(K) + 2\text{Log}(L\infty)$.

Mortality Estimate: The natural mortality rate (M) is evaluated using the empirical formula (Then et al. 2015): $M = 4.118 \times K^{0.73} \times L\infty^{-0.33}$

$L\infty$ is fish infinite length (cm), K is growth curve parameter of von Bertalanffy equation.

Total mortality (Z) found out using data from the length - converted catch curves. The fishing mortality (F) was estimated using the relationship $F = Z - M$. The fishing mortality (F) of Maximum sustainable yield (MSY) were determined Using the formula $F_{MSY} = M$ (Zhou et al. 2017). The exploitation rate (E) was the ratio of fishing mortality (F) to total mortality, which was calculated using the formula $E = F/Z$ (Sparre & Venema 1998).

Length-based reference point (LBRP): Length-based reference point (LBRP) suggests using three different measurements: 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 Lopt and Lmax on the catch length composition) in the catch (Pmega). These three measurements are all combined to give an overall score called the Pobj value, which can help to understand fishing status (Cope & Punt 2009). Length at maturity (Lmat) of *T. albacares* was 76 cm in the northern part of the Oman Sea near Iran, according to Keymaram et al. (2009).

The optimal fishing length (called LF=M) calculated using some calculations as follows (Cousido-Rocha et al. 2022):

$L_{opt} = L_{inf}\ (3/(3+M/K))$

$L_{F=M} = (0.75L_c + 0.25L_{inf})$

$P_{mega} = L_{opt} + \%10$

Length-based Spawning Potential Ratio (LBSPR): LBSPR is one of the biological reference points for determining the stock status. The reference points of LBSPR has two important points: LBSPR 20% is as limit reference point and LBSPR 40% is a target reference point (Hordyk *et al.*, 2015). The SPR was described by Hordyk et al. (2015):

$\text{LBSPR} = \dfrac{\sum(1-LX)^{(M/K)[(F/M)+1])L_x^b}}{\sum(1-L_X)^{\frac{M/K}{L_x^b}}}$, Where: Lx, M, K, F are fork length; natural mortality; growth rate; fishing mortality, respectively. The SPR were determined using the simple assumptions of asymptotic or logistic selectivity functions, with this assumption that the fish catch only in certain sizes and not considered age differences. The F/M ratio can be estimated from the length composition of the catch (Hordyk *et al.*, 2015). The connection between F/M and SPR is asymptotic and based on the selectivity parameters (Carruthers & Hordyk 2018).

Stock status: The Stock status of *T. albacares* were also evaluated. For this purpose, at first exploitation rate (U) was estimated using the equation given by Beverton & Holt (1957) as $U = F\ (1-e^{-z})/Z$. To estimate the annual catch ($Y_{1992} = 14000$ t, $Y_{2022} = 44000$ t), the landing data of Yellowfin tuna were collected from Iran Fisheries Organization (IFO 2023). Then by using the values of U, Initial biomass or virgin biomass ($K = B_v = Y/U$), average standing stock ($B_t = Y/F$; Pillai et al. 2000) and biomass of Maximum sustainable yield (MSY) ($B_{MSY} = K/2$) were determined (Zhou et al. 2017).

Statistical analyses: Comparison of population dynamic, lengths and weights value in different of years were tested by independent *t*- test. Data analyses were performed using R (4.3.0), R Studio software (2023. 06.0) with the TropFishR and LBSPR packages.

RESULTS

Length frequency distribution: The mean±standard deviation of fork length (L) and total weight (W) for 1992 (3700 specimens) and 2022 (2600 specimens)

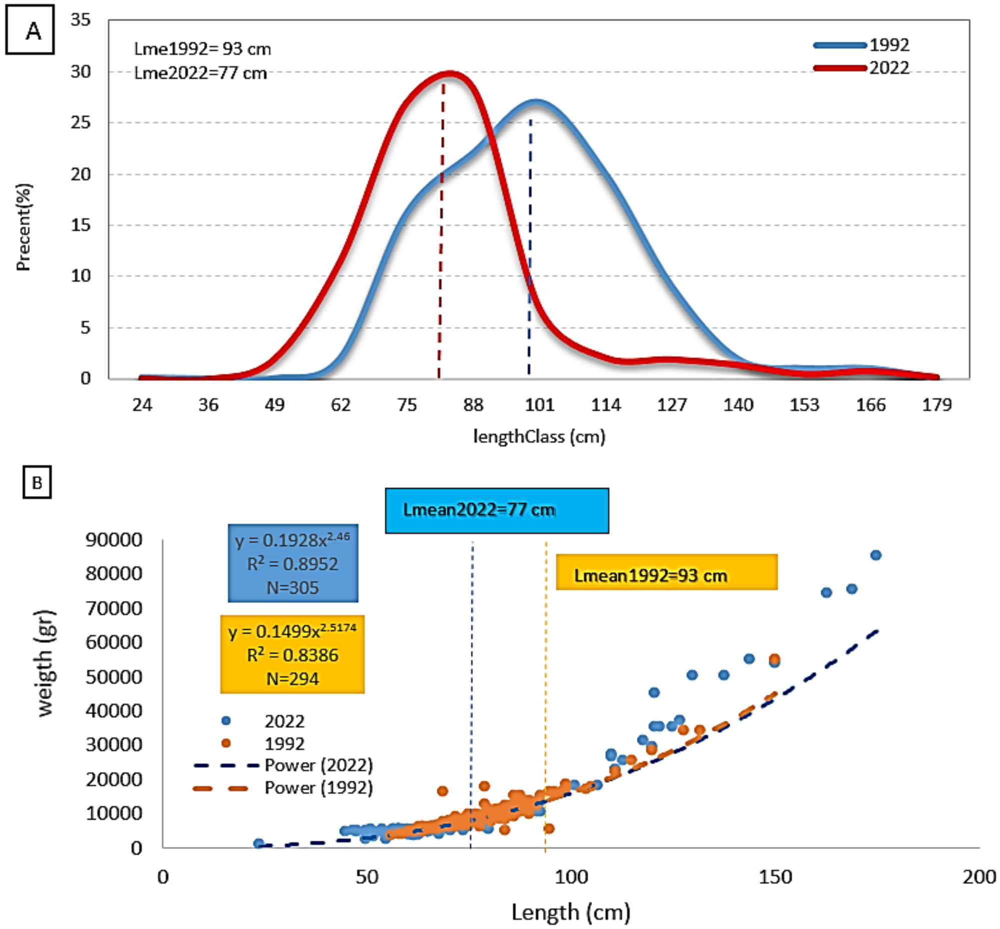

Fig.2. Length and percentage frequency in different length categories (A) and Length-weight relationship (B) of *T. albacares* in the northern waters of the Oman Sea.

were 93±26 (21-157) cm, 77±18 (24-175) mm respectively, and, 9127±1251 (3500-55000) g, 10639±1450 (1100-85000) g respectively. The differences between length and weight in both years were significant (t = 29.76, P< 0.05), (t= 38.39, P<0.05) respectively). The length (TL) data were categorized into 13-cm groups which the highest frequency, have a place with 88 to 101cm length (1992) and 75 to 88cm length (2022) (Fig. 2).

Length-weight relationship (LWR): The relationship between length and weight was calculated for two years by following Equation (1) and give a=0.14 and b= 2.51 (R^2= 0.83) for 1992, and for 2022, a= 0.19 and b= 2.46 (R^2= 0.89). The student –test has shown significant differences between estimated b and b= 3 at the level of 0.05 (Fig. 2), which means allometric growth pattern (negative) for *T. albacares* in the northern part of the Oman Sea. The LWR of *T. albacares* fish shows that in similar length groups, have less weight in 2022 compared to 1992.

Population dynamic parameters: Table 1 shows population dynamic parameters of Yellowfin tuna in 1992 and 2022. Growth parameters for 1992 and 2022 were estimated, as L∞= 182cm, K= 0.39 (yr^{-1}), t_0= -0.25 and L∞= 177cm, K= 0.55 (yr^{-1}), t_0= -0.18, respectively. The growth curve (Figure 3), indicated 6 cohorts (age groups) and the growth performance index was estimated as Φ= 4.11 and 4.21 for 1992 and 2022, respectively. Based on the results, the maximum lifespan of this species was near 7.7 to 5.5 years, respectively. The natural mortality (M), fishing mortality (F) and total mortality (Z) were estimated as 0.56, 0.49 (yr^{-1}), 1.28, 1.92 (yr^{-1}), and 1.94, 2.41 (yr^{-1}) for 1992 and 2022, respectively (Table 1). The exploitation coefficient was estimated as 0.7 and 0.8 (yr^{-1}), respectively.

Length-based indicators (LBI) and Length-based Spawning Potential Ratio (LBSPR): The length-based

Table 1. Comparison of population dynamics values of *T. albacares* in two years *(*1992-2022) in the northern waters of the Oman Sea. ($L\infty$= infinite length, K= Growth rate, t_o= time that length is zero, M= Natural mortality, F= Fishing mortality, Z= Total mortality, E= Exploitation rate, F_{MSY}=Fishing mortality of Maximum sustainable yield (MSY), B_{MSY}= Biomass of Maximum sustainable yield (MSY), B_V= Initial biomass or virgin biomass, LBSPR= Length-based Spawning Potential Ratio).

Year	L_∞ (cm)	K (yr^{-1})	t_o	Φ	M (yr^{-1})	F (yr^{-1})	Z (yr^{-1})	U	E	F/F_{MSY}	B/B_{MSY}	B/B_v	LBSPR
1992	182	0.39	-0.25	4.11	0.56	1.28	1.94	0.56	0.7	2.28	0.87	0.43	0.22
2022	177	0.55	-0.18	4.21	0.49	1.92	2.41	0.72	0.8	3.91	0.75	0.37	0.10

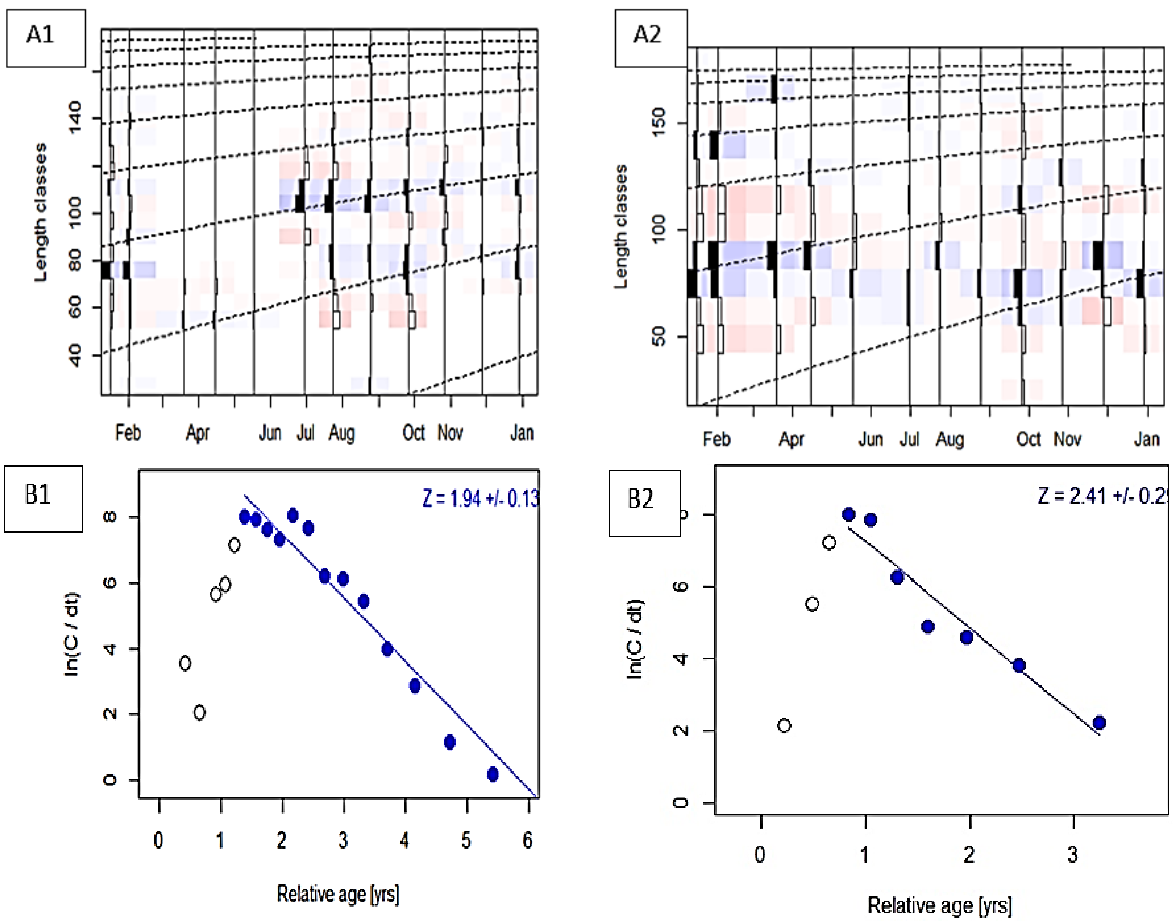

Fig.3. Growth curve derived from the structure of population (A1= 1992, A2= 2022) and exploitation coefficient curve (B1= 1992, B2= 2022) of *T. albacares* in the northern waters of the Oman Sea.

reference point is the percentage of fish that are caught at the best length for harvesting (L_{opt}= 123mm, P_{opt}= 0.009), (L_{opt}=132mm, P_{opt}= 0.01) and ($L_{F=M}$= 100mm, $P_{F=M}$= 0.47), ($L_{F=M}$= 91mm, $P_{F=M}$= 0.14). The percentage of mega-spawners in the catch is also measured for 1992 and 2022 this species (L_{mega}= 132cm, P_{mega}= 0.009), L_{mega}=145 cm, P_{mega}= 0.01), respectively.

The ratios of P_{mega} less than 0.1, L_{mean}/L_{opt} less than 1 and $L_{mean}/L_{F=M}$ less than 1 were estimated. The ratio of spawning potential based on length (LBSPR) in 1992 and 2022 were 0.22 (0.20-0.25) and 0.10 (0.09-0.12), respectively (Table 1 and Fig. 5). In 1992, only 18% of the samples were lower than mature length, and in 2022, this number increased to about 42%. It value showed a significant difference for 1992 and 2022 (*t*= 94, P< 0.05). The value of infinite length, average length, and maximum length of 2022 shows a significant decrease compared to 1992 (P< 0.05, Fig.

4). Also, the optimal length (Lopt) shows a significant increase in this period of time (t= 35, P<0.05).

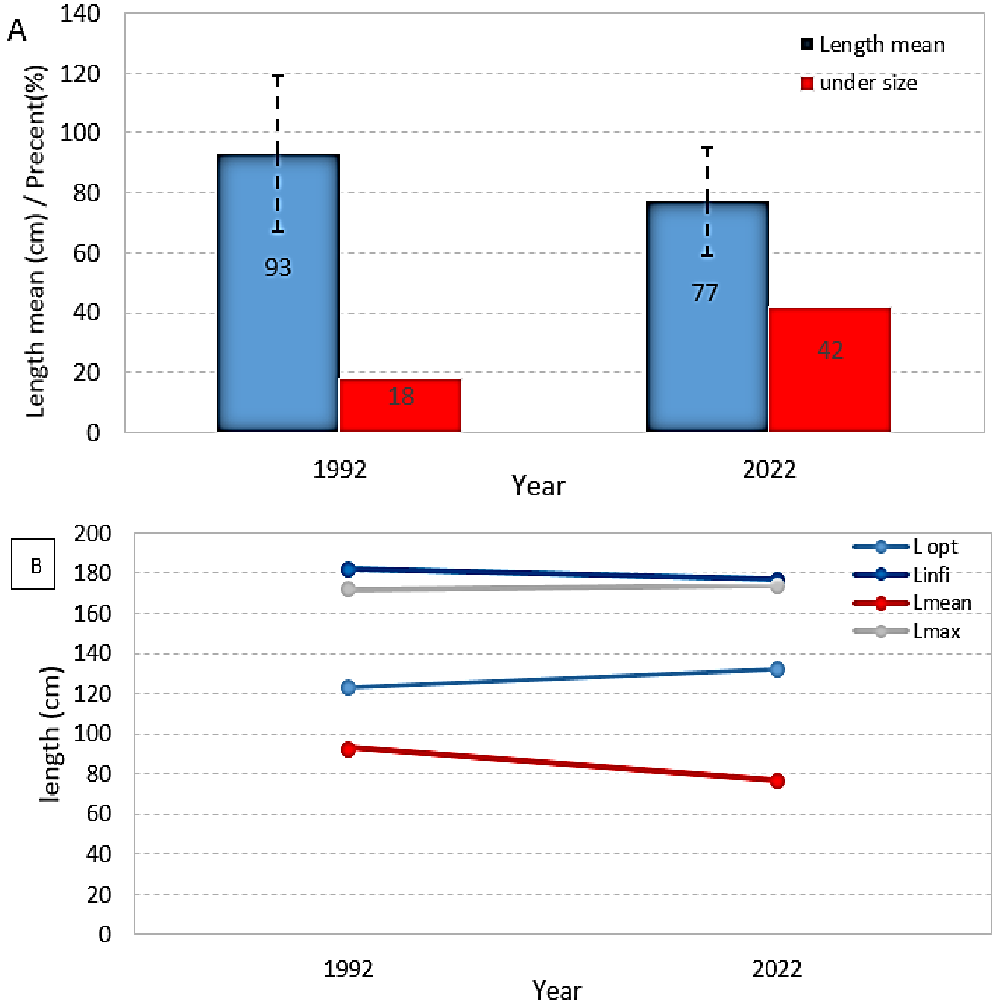

Fig.4. Length mean and under size percent (A) and length-based reference point (B) in two years (***1992-2022)*** of *T. albacares* in the northern waters of the Oman Sea.

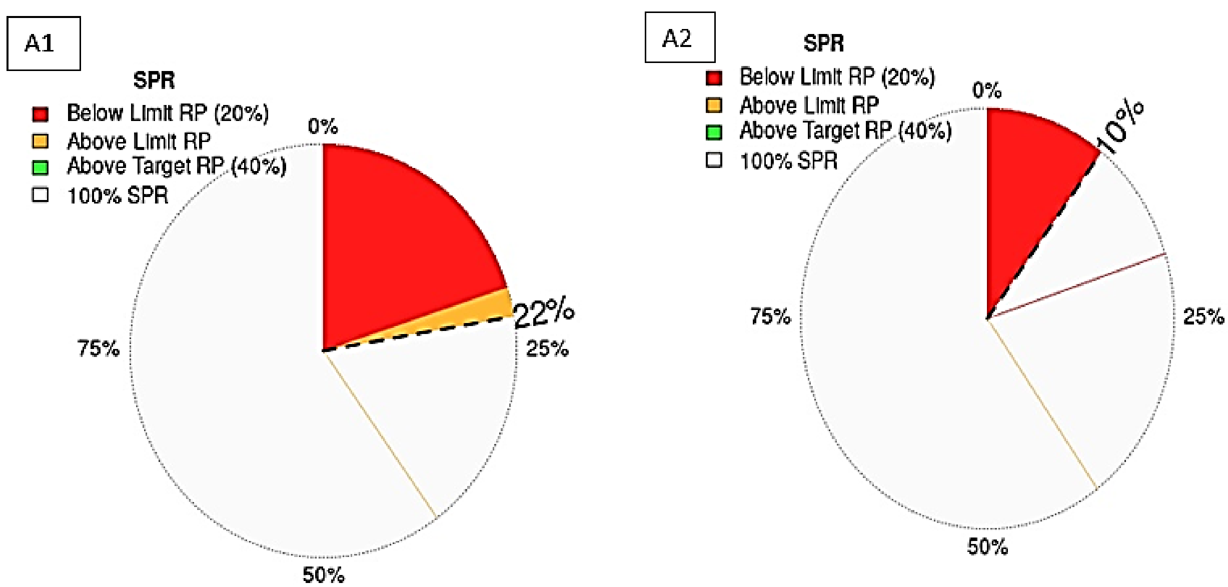

Fig.5. The LBSPR (A1= 1992, A2= 2022) value of *T. albacares* in the northern waters of the Oman Sea.

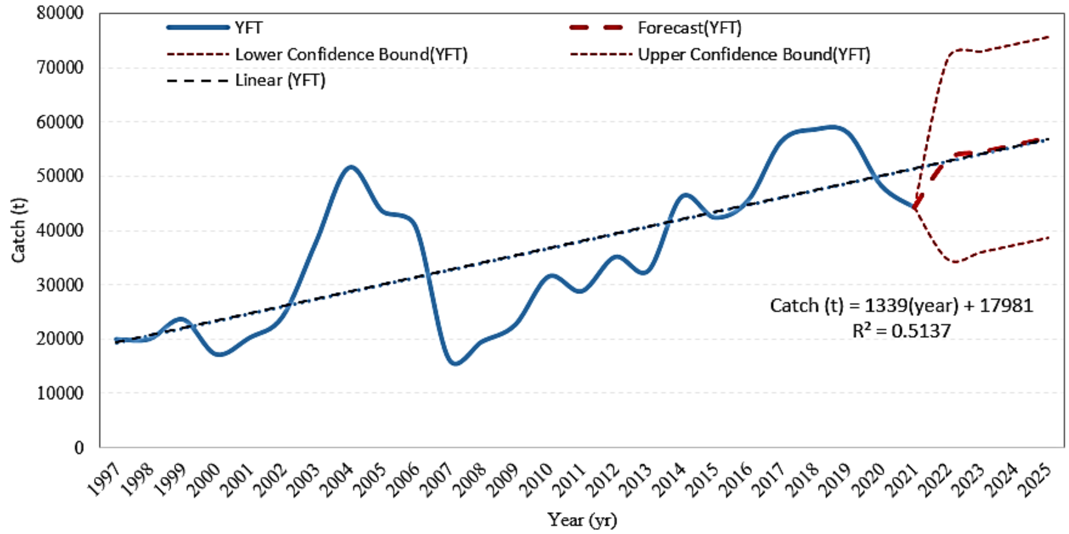

Fig.5. The catch value of *T. albacares* in the northern waters of the Oman Sea.

Stock status: Initial biomass or virgin biomass (K_{1992}~25000 t, K_{2022}~61000 t), average standing stock (B_{1992}~10900 t, B_{2022}~22900 t) and biomass of MSY ($B_{MSY1992}$~12500 t, $B_{MSY2022}$~30500 t) of *T. albacares* for different years (1992 and 2022) were estimated. The F/F_{MSY}, B/B_{MSY} and B/B_v values are shown in Table 1.

DISCUSSION

T. albacares is an important fish in the southern part of Iran. In recent years, there has been more of this fish caught in the northern area of the Oman Sea in Iran. Over 44,000 tons of this fish have been caught in the South of Iran's waters (Fig. 6). The majority, more than 89 percent, of this fish catch is from the northern Oman Sea, Sistan and Baluchistan Province (IFO 2023). Based on the linear average of catch of Yellowfin tuna, forecast shows an increase until 2025, in the northern waters of the Oman Sea, Iran (Fig. 6).

Population dynamic of Yellowfin tuna: The biological characteristics of this species were compared with other studies from different parts of the world. The comparison results are shown in Table 3. It appears that the Yellowfin tuna in the Oman Sea regions are smaller compared to the Yellowfin tuna in the east coast of India, Indonesia, and the Arabian Sea regions. It is expected that this species grows more in tropical regions than subtropical regions and its reasons are the temperature difference and its ecological conditions. The estimate for the $L\infty$ of yellowfin tuna in this study is lower than the one given by Kaymaram et al. (2000) and (2014). The K estimate was found to be higher than the estimate provided by Kaymaram et al. (2000) and (2014), and it can be for various reasons. One possible reason might be due to overfishing, or it could be because the method used to collect samples. The differences in amounts of the infinite length and growth rate are affected by the differences in the environment in each area (King 2007). Usually, regions can have different lengths and growth rates due to the amount and quality of food and the weather conditions (Bartulovic et al. 2004). Various factors can impact fish grow such as their age, sex, season, year, type of feeding, physiological conditions, availability of food resources and reproductive time (Lalèyè 2006). The amount of fish in an area is affected by various things like the weather, the conditions of the ocean, and the relationship between the fish and their predators (Vivekanandan 2005; Hashemi et al. 2021; Hashemi et al. 2022; Hashemi & Doustdar 2022).

The Growth performance index (Φ') was measured to be 4. 21, which is similar to other study conducted by Kaymaram et al. (2014), Haruna et al. 2018; this information could be found in Table 2. The reason for comparing Φ' values of the growth curve is because there is a connection between infinite length and growth rate, and this index has constant changes

Table 2. Comparison of biological characteristics of *T. albacares* with other studies around Indian Ocean.

References	Region	$L\infty$ (cm)	K (yr^{-1})	t_o	Φ'	A (yr)	M	F	Z	E
Maldeniya & Joseph (1986)	Sri Lanka	178	0.47	-0.2	-	6.3	-	-	-	-
Anonymous (1987)	Sumatra	175	0.5	-	-	-	-	-	-	-
John & 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
Hashemi et al. (2020)	Oman Sea (Iran)	171	0.54	-0.18	4.19	5.38	0.71	1.57	2.28	0.68
Present study	Oman Sea (Iran)	177	0.55	-0.18	4.21	5.5	0.49	1.92	2.41	0.8

at different times and in different sizes. Changes in the environment and location can impact infinite length and growth rate. These differences include different values of Φ' and can also vary within one area in different time periods because changing environmental conditions (King 2007).

The value of indices of exploitation coefficient and exploitation rate in the population must be less than 0.5 or fishing mortality should not be more natural mortality. These indices indicate overfishing (Sparre & Venema 1998; King 2007).

Other past studies on this species in the Indian Ocean have shown the amount of natural mortality (M)in the range of 0.4 to 0.7 per year, fishing mortality (F) in the range of 0.2 to 1.5 per year, total mortality (Z) in the range of 0.7 to 2 per year and exploitation coefficient in the range of 0.3 to 0.7 per year (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; Hashemi et al. 2020). This study affirms to past considers on *T. albacares* in the region (Kaymaram et al. 2014; Hashemi et al. 2020) which shown overfishing status. According to Froese & Pauly (2022), maximum lifespan of *T. albacares* was estimated around five years old using a mathematical formula (t_{max}= t_0+3/K). Based on American Fisheries Society (AFS) and comparing our findings with their standards (Cheung *et al.,* 2004), extinction vulnerability of this species was estimated to be high.

The Yellowfin tuna fish have been evaluated overfishing and overfished in the Indian Ocean with Maximum Sustainable Yield (MSY)*,* 403(339-436) thousand ton, B_{MSY}= 1069(789-1387) thousand ton, F_{MSY}=0.15 (0.13–0.17), F/F_{MSY}= 1.20(1.00–1.71), B/B_{MSY}= 0.83(0.74–0.97), B/B_v= B_0= 0.30(0.27–0.33) (IOTC 2020). The main factors that impact pressure on fish populations are the amount of fish caught and the environment, which affects their ability to survive and find food and resources (Mateus & Estupinan 2002).

Length-based indicators (LBI) and Length-based Spawning Potential Ratio (LBSPR): The L_{mean}/L_{opt} index shows presence of overfishing with values less than 1, and also $L_{mean}/L_{F=M}$ index shows values less than 1 and P_{mega} less than 0.1 is calculated which indicated undesirable condition. The desired range for the L_{mean}/L_{opt} and $L_{mean}/L_{F=M}$ indexes is close to 1 and

P_{mega} is around 0.3-0.4(Cousido-Rocha et al. 2022). Furthermore, nearly 42% of the individuals of this species had a length below of length at maturity (L_{mat}), which is concerning.

The LBSPR rate of this species is 0.1 (% 10), and LBSPR provides estimates of the spawning potential ratio (SPR). If this index value is below 0.2 (≈ 0.5 B/B_{MSY}), it means the stock is depleted. If the value is above 0. 4 **(≈** 1.0 B/B_{MSY}**)**, it means the stock is in good condition. In conclusion, the LBSPR model is a useful tool for measuring the size of fish stocks with limited data (Hordyk et al. 2015). In simple words, scientists have come up with ways to easily and cheaply measure the size and characteristics of an exploited stock. One example is the length-based spawning potential ratio method (Hordyk et al. 2015)

Management and exploitation of this species in the Oman Sea: This parameter helps manage for fisheries management, protect the population of yellowfin tuna in the northern waters of the Oman Sea. Overfishing can happen when decrease of the average length and LBSPR index and increase of fishing and total mortality. This study found that the yellowfin tuna population has reached 'overfished' status, which is not good. It is suggested to create clear instructions for exploitation and management of *T. albacares* in the region. The findings of this study can assist management and sustainable harvest of this species stocks.

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مقاله کامل

تغییرات پارامترهای جمعیتی مبتنی بر طول تون ماهی زردباله (*Thunnus albacares* Bonnaterre, 1788) طی دو دوره زمانی در آب‌های شمالی دریای عمان

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چکیده: این تحقیق به اطلاعات اولیه در مورد ماهی تون زرد باله (گیدر) در بخش شمالی دریای عمان نگاه داشته و اطلاعات مفیدی در مورد نحوه مدیریت صحیح این ذخیره ارائه می‌دهد. در طول سال‌های این مطالعه (۱۹۹۲ و ۲۰۲۲) بیش از ۶۰۰۰ ماهی اندازه‌گیری شد و میانگین طول (دامنه) ماهی تون زرد باله (گیدر) در سال‌های ۱۹۹۲ و ۲۰۲۲ به‌ترتیب ۲۶±۹۳ (۱۵۷-۲۱) سانتی‌متر و ۱۸±۷۷ (۱۷۵-۲۴) سانتی‌متر بود. میانگین وزن (دامنه) این گونه به‌ترتیب ۱۲۵۱±۹۱۲۷ (۵۵۰۰۰-۳۵۰۰) گرم در سال ۱۹۹۲ و ۱۴۵۰±۱۰۶۳۹ (۸۵۰۰۰-۱۱۰۰) گرم در سال ۲۰۲۲ بود. رابطه بین طول چنگال و وزن کل بدن برای سال ۱۹۹۲، $W=0.014\times L^{2.51}$ (R^2=0.83, N=750) و سال ۲۰۲۲، W=0.019×L2.46 (R^2=0.89, N=703) به‌دست آمد. معادله ون برتالانفی برای این گونه در آب‌های شمالی دریای عمان (ایران) در سال‌های ۱۹۹۲ و ۲۰۲۲ به‌ترتیب به‌صورت: ((Lt=182 (1-exp (-0.39 (t +0.25 و (Lt=177 (1-exp (0.55- (t +0.18 محاسبه شد. نسبت پتانسیل تخم‌ریزی براساس طول (LBSPR) در سال ۱۹۹۲ و ۲۰۲۲ به‌ترتیب ۰/۲۲(۰/۲۵-۲۰/۰-۰/۰) و ۰/۱۰ (۰/۱۲- ۰/۰۹) بود. بر اساس نسبت Pmega <0.1، Lmean/Lopt <1 و Lmean. /LF=M 1> نشان می‌دهد، وضعیت بهره‌برداری از ذخیره در شرایط نامطلوب قرار دارد. کاهش میانگین طول، شاخص LBSPR و افزایش صید و مرگ و میر کل می‌تواند دلیلی برای صید بی‌رویه باشد. مطالعه حاضر نشان داد که ذخیره ماهی تون زرد باله (گیدر) به وضعیت صید بیش از حد رسیده است. یافته‌های این مطالعه می‌تواند به مدیریت و برداشت پایدار ذخایر این گونه کمک کند.

کلمات‌کلیدی: صید بی‌رویه، نسبت پتانسیل تخم‌ریزی، معادله ون برتالانفی، برداشت پایدار.