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Research Article

Population dynamics and fishery status of *Trichiurus lepturus* (Largehead hairtail) in the northern waters of the Oman Sea (Sistan and Baluchestan waters, Iran)

Taghavi Motlagh S.A.[1]; Hashemi S.A.R.[2]; Mirzaei M.R.[2]*

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Abstract

Population dynamics and fishery status of *Trichiurus lepturus* were estimated by landings data on the northern waters of the sea of Oman (Sistan and Baluchestan Province, Iran). A total of more than 3000 fish samples were weighted and measured during one-year study period (October 2016 to September 2017), the growth indices were obtained as follow: $L\infty$=176 cm, K=0.5 (yr^{-1}), t_o=-0.2 year, M=0.67(yr^{-1}), F=3.52 (yr^{-1}), Z=4.19 (yr^{-1}), and E=0.85, respectively. Exploitation rate (U), 0.53, annual total stock at the beginning of the year (Bv), 32264 t, Annual average standing stock (B), 4827 t, Maximum Constant Yield (MCY),10260 t, maximum sustainable yield (MSY),15390 t, fishing mortality rate that maximizes equilibrium yield per recruit, F_{max}: 0.8 and Exploitation ratio maximum sustainable yield, E_{msy}: 0.54 were calculated for this species. Results of this study showed exploitation ratio of the Largehead hairtail stock is overfishing and decreasing of exploitation rate proposed.

Keywords: Largehead hairtail, Catch trend, Exploitation rate, Oman Sea

1-Iranian Fisheries Science Research Institute (IFSRI), Agricultural Research, Education and Extension Organization (AREEO), Tehran, Iran.
2-Off-shore Fisheries Research Center, Iranian Fisheries Science Research Institute (IFSRI), Agricultural Research, Education and Extension Organization (AREEO), Chabahar, Iran.
*Corresponding author's Email: mirzaei.mr@gmail.com

Introduction

Management of sustainable harvest in marine resources depends on assessment of the exploitation status (Kokkalis *et al*., 2016). Knowledge regarding the status of a fishery resource derived from different sources: control and evaluation the fishery (landing, catch, and effort data); biological studies, resource users, and similar resources in other locations. Often the only data available to infer the status of a fishery in a particular location are the landings in weight or number of the targeted species (Kruse *et al*., 2005). The data collection is the primary form of fisheries assessment and management. Nevertheless, limited data may be a considerable concern in an area, particularly in most species-rich natural communities (Kruse *et al*., 2005). Fishery status showed that around 30% of all fisheries were collapsed, 40% more were overexploited, and the percentage of collapsed and overexploited fisheries will increase over time (Worm *et al*., 2006). Data of FAO catch showed 32% of global fisheries were developing, 27% fully exploited, 25% overexploited, and 16% collapsed or closed (Anderson *et al*., 2012).

The largehead hairtail lives in coastal waters in depth of 50-100 m of the warm-temperate and tropical marine environments. In the daytime, juvenile and small fish shoaling together at around 100 m depth (Froese and Pauly, 2019). Mirzaei *et al.* (2019) stated that the highest abundance of largehead hairtail observed in the depth between 50-100 m in the Gulf of Oman. Adults' beltfish feed on pelagic fish throughout the day and accumulate in shallow muddy waters in bays, estuaries and coastal areas during the night-time (Froese and Pauly, 2019). Juveniles and small adults form schools at 100 m depths during the daytime, and they form loose feeding aggregations at night near the surface (Kleiman *et al*., 2003, Shojaei and Taghavi motlagh, 2011).

Increased fishing pressures have led to reducing body size and increased maturational rate. In some countries it represents an exploitable fish, is ranked in the sixth place of landing volume worldwide (Lijun He, 2014). The average annual catch of the largehead hairtail during 2008 to 2017 was around 6400 tones, rate catch of this species in 2017 was more than 17,000 tons (the northern waters of the Oman Sea) and has grown significantly (Fig. 1) in recent years (IFO, 2019).

This species has played economically a great role in the Persian Gulf and Oman Sea fisheries. Despite the economic importance of this species, little is known about the biology of this species in the northern waters of the Oman Sea, but some studies has been carried out (Taghavi moltlgh, 2010; Raeisi *et al*, 2011; Taghvimotlagh and Shojaei, 2017). The study objectives are to provide information regarding biological reference points and other population dynamics information required for management of this species in northern Oman Sea.

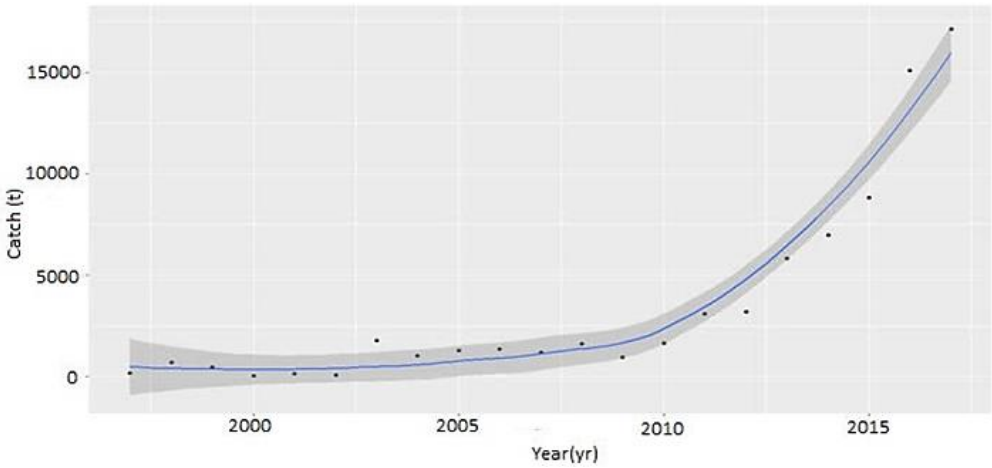


Figure 1: Catch amount of largehead hairtail in the past two decades (1997-2017), Sistan-Baluchistan coastal waters in the northern waters of the Oman Sea.

Materials and methods

The length frequency data was collected monthly from four sampling stations (Beris (61˚ 10´E, 28˚ 82´N), Ramin (60˚ 45´E, 25˚ 15´N), Pozm (60˚ 28´E, 25˚ 14´N) and Konarak (60˚ 28´E, 25˚ 60´N)) (Fig. 2). Total lengths of 3466 *T. lepturus* individuals (±1.0 mm) caught by bottom trawl and gill net were measured during 2016-2017.

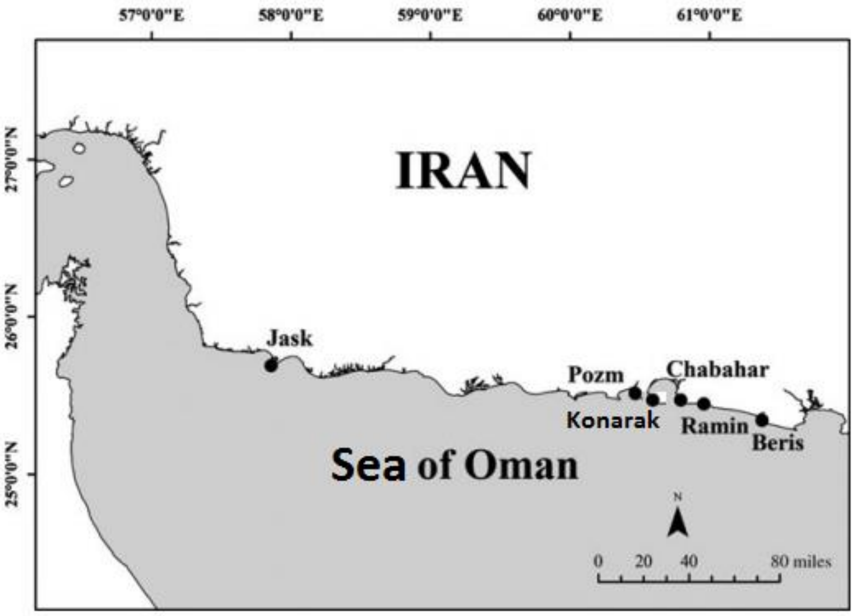


Figure 2: Location of landing sites of largehead hairtail in the northern waters of the Oman Sea.

Growth studies

The collected length frequency was grouped into 8 mm class intervals. The length infinity (L∞) was estimated by Powell and Wetheral plot and the growth rate (K) was obtained by applying the ELEFAN (Electronic Length Frequency Analysis) method (optimization model), RStudio software and TropFishR package (Mildenberger *et al*., 2017) and ELEFAN I programe in FiSAT II (FAO-ICLARM Stock Assessment Tools) developed by Gayanilo *et al.* (2002). The parameter t_0 of the growth equation was estimated using the following equation (Pauly, 1980):

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

In order to facilitate the comparison of the results with those of other studies, growth performance index (Φ′) was estimated by the following equation (Pauly and Munro, 1984):

$\Phi' = \log(K) + 2\text{Log}(L_\infty)$

Mortality estimate

The total mortality coefficient was estimated by length converted catch curve of Pauly (1980):

$$Ln\left(\frac{N}{\Delta t}\right) = a + b \times t$$

Where, b=Z (Total mortality rate) with the sign changed. The instantaneous rate of natural mortality (*M*) was estimated using the following multiple regression model (Pauly, 1980).

$$\text{Log}\ (M) = -0.0066 - 0.279\log(L_\infty) + 0.6543\log(K) + 0.4634\log(T)$$

The mean annual environment temperature (T) used in the estimation was 26°C (Taghavi motlagh, 2010; Taghavi motlagh and Shojaei, 2017). Fishing mortality rate (F) was calculated as (Sparre and Venema, 1998), F = Z - M.

The exploitation rate (U), was estimated by $U=F\ (1-e^{-z})/z$ (Pauly, 1983). The annual total stock at the beginning of the year (Bv) was estimated by Y/U where Y is the annual average catch of the species (Nurulamin *et al*., 2000).

Stock assessment

Annual average standing stock (B) was estimated by: Y/F (Nurulamin *et al*., 2000). MCY was estimated by the equation: MCY=c×Yav (Annala, 1993). Where Yav is the average catch of the species over an appropriate time period and c is natural mortality factor of the species (0.6 is here). MSY was estimated by the equation:

MCY=2/3×MSY (Jenning *et al*., 2000).

The relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R) were conducted to obtain reference points and determined the exploitation status. The model of Pauly and Soriano (1986) was used to predict the relative yield per recruit (Y/R) as follows:

$$Y'/R = EUM/k\ [1-(3U/1+m) + (3U^2/1+2m) + (U^3/1+3m)]$$

here: m=(1 – E)/ (M/k)=k/Z, $U=1-(L_c/L_\infty)$, E=F/Z and B'/R=(Y'/R)/F (Gayanilo *et al*., 2003). The relative biomass per recruit (B'/R) was estimated by B'/R=(Y'/R)/F (Gayanilo *et al*., 2003).

Relative yield and biomass per recruit analyses were conducted using growth and mortality parameters and selectivity gives derived from probability of capture data. Statistical analyses were performed with SPSS 21 and R Studio (1.1.463) software packages.

Result

Growth studies

Mean±S.D length values, minimum and maximum total length of this species were 80±10 cm, 22 and 142 cm, respectively (Table 1 and Fig. 3). The growth parameters of von Bertalanffy equation (males and females combined) were as, L_∞: 176 cm and K: 0.5 (year^{-1}) and t_0: -0.2 (year^{-1}) (Fig. 4). The value of growth performance index, Φ', estimated from the growth parameters was 4.18, which gave the Von Bertalanffy growth equation for this species as: Lt=176 (1-exp (-0.5 (t+0.2))).

Table 1: Average values (±S.D.) of size corresponding of largehead hairtail in the northern waters of the Oman Sea.

Month	Number of captured	Mean TL±S. D (cm)	Min – max (cm)
January	240	87±9	71-118
February	162	78±8	62-108
March	565	85±11	37-142
April	252	86±9	46-124
May	198	76±15	22-121
June	95	77±8	60-93
July	626	79±12	45-118
August	330	81±10	58-115
September	358	75±7	58-114
October	240	75±8	48-104
November	200	77±8	62-128
December	200	81±8	59-105
Average	-	10±80	22-142

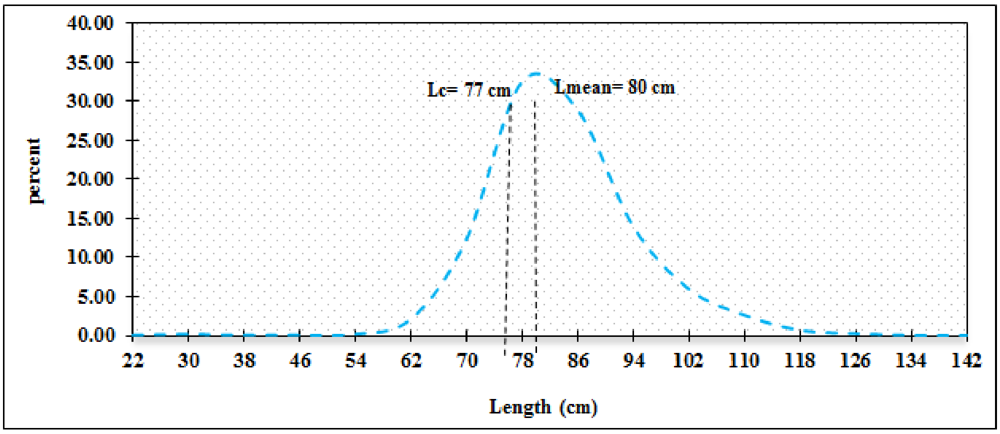
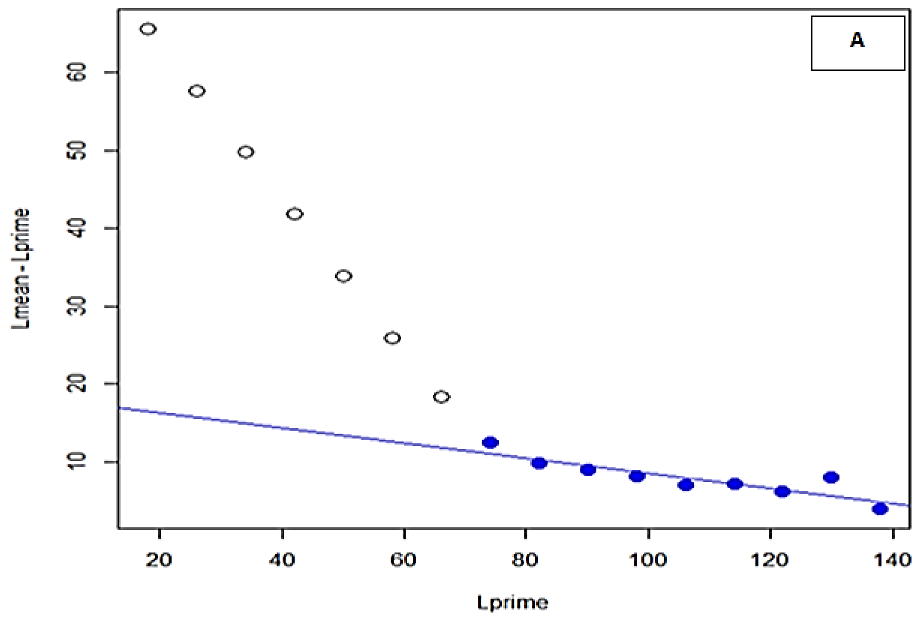


Figure 3: Length frequency distribution of largehead hairtail in the northern waters of the Oman Sea., Lc= length which the probability of fish capture is 50 %, Lmean= Mean of total length.



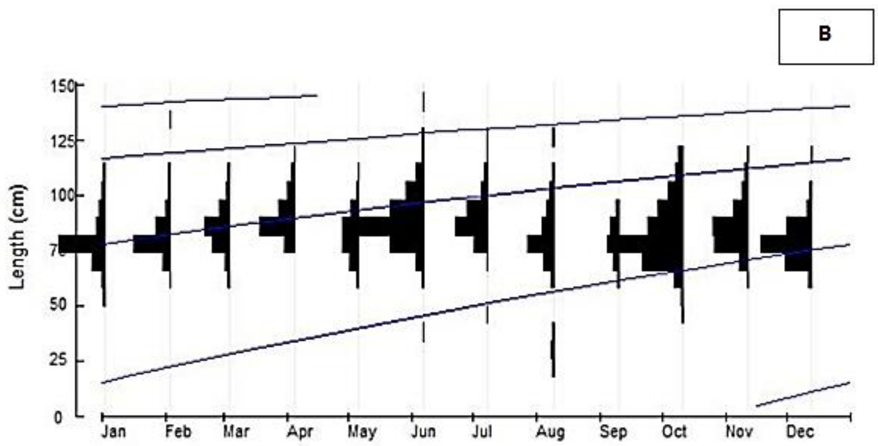


Figure 4: Powell and Wetheral plot (A) and Growth curve (B) of largehead hairtail estimated on the restructured length-frequency diagram (L∞=176cm and K=0.5 yr^{-1}).

Mortality rates, relative and biomass per recruit

The annual instantaneous rates of fishing induced mortality (F), natural mortality (M) and total mortality (Z) are given in Fig. 5. The totlal mortality coefficient (Z) was calculated as 4.19 year^{-1} by pauly's length converted catch curve method (Fig. 4). The annual mortality coefficient (M) was estimated as 0.67 year^{-1} by paulys method. The fishing mortality (F) was 3.52 year^{-}1. The exploitation rate was calculated to be 0.84. The ratio of actual number caught by length class estimated using ELEFAN II, correcting each length class for mesh selectivity. Values of L25 %, L50 %, and L 75% were 71, 77, and 84 cm, respectively.

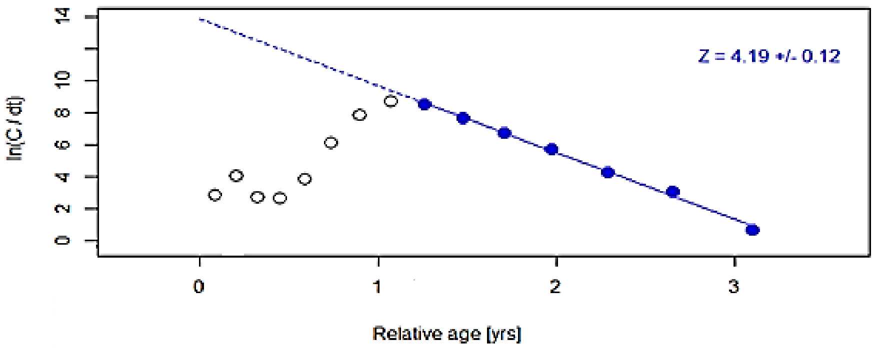


Figure 5: The graphic output of the catch curve analysis for largehead hairtail.

Stock assessment

The relative yield-per-recruit (Y'/R) and biomass-per-recruit (B'/R) were determined as a function of Lc/L∞ and M/K. Lc estimated at 77 cm and Lc/ L∞ and M/K were 0.43 and 1.34 respectively. Relative yield per recruitment (Y'/R) calculated as 0.04 and relative biomass per recruitment, (B'/R) calculated as 0.04 for this species (both sex) stock was calculated (Fig.6). The size at which yield per recruit would be maximized (L_{max}=100 cm) approximated the mean size of fish that were 1.5 years old and was considerably greater than the mean size at first capture. Exploitation rate (U), 0.53, annual total stock at the beginning of the year (Bv), 32264 t, annual average standing stock (B), 4827 t, Maximum Constant Yield (MCY), 10260 t, maximum sustainable yield (MSY),15390 t, fishing mortality rate that maximizes equilibrium yield per recruit, F_{max}: 0.8 and Exploitation ratio maximum sustainable yield, E_{msy}: 0.54 for this stock was calculated (Table 2).

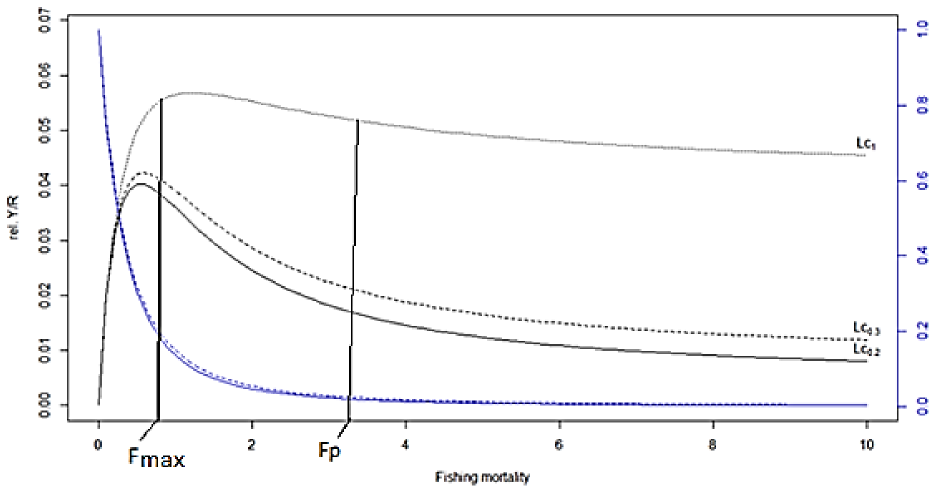


Figure 6: Relative yield and biomass per recruit curves (descending lines) for largehead hairtail showing the existing fishing mortality (Fp= fishing mortality of present and F max= fishing mortality of maximizes equilibrium) and different Lc.

Table 2: Estimate mortality and yield of largehead hairtail in the northern waters of the Oman Sea.

Year	Emax	E0.1	E0.5	B'/R	Y'/R	Fmax	B	Bv	MCY	MSY
2016-17	0.59	0.50	0.34	0.04	0.04	0.8	4827	32264	10260	15390

Dsicussion

By comparing the growth parameters of *T. lepturus* with other studies in different parts of the world, it was concluded that this species in the Persian Gulf and Sea of Oman, has an asymptotic length (L∞) longer than China Sea, the Philippines, and the Yellow Sea. In addition, the length of *T. lepturus* species in Oman Sea is larger than species in the Persian Gulf and the growth coefficient (k) of this species in different regions does not seem to have a clear trend (Table 3).

Table 3: Biological and mortality parameters of largehead hairtail in different parts of the world.

Different parts	Biological and mortality parameter									Reference
	Length	Sex	E	Z (yr^{-1})	F (yr^{-1})	M (yr^{-1})	Φ'	K (yr^{-1})	L_{∞} (cm)	
India (East coast)	Total	Both	-	-	-	-	3.78	0.29	145	Narasimham, 1976
China Sea	Anal	Both	-	-	-	-	-	0.11	70	Lin and Zhang, 1981
Taiwan	Anal	Both	-	-	-	-	-	0.72	50	Chen and Lee, 1982
Philippian	Anal	Both	-	-	-	-	-	0.7	78	Ingles and Pauly, 1984
India (West coast)	Total	Both	-	-	-	-	3.88	0.64	109	Somavanshi and Antony, 1989
India (West coast)	Total	Both	0.46	1.96	0.91	1.05	3.92	0.5	129	Chakraborty, 1990
India (West coast)	Total	Both	-	-	-	-	3.97	0.56	129	Thiagarajan *et al*.,1992
India (East coast)	Total	Both	0.92	3.10	2.7	0.4	-	-	138	Narasimham, 1994
India (East coast)	Total	Both	0.71	2.66	1.52	0.89	3.83	0.61	106	Reuben *et al*., 1997
China Sea	Anal	Both	-	-	-	-	-	0.17	58	Kwok and Ni, 2000
India (West coast)	Total	Both	0.71	2.66	1.89	0.77	3.91	0.5	128	Mohite and Biradar, 2001
India (West coast)	Total	Both	0.3	0.44	0.13	0.31	3.72	0.13	131	Fofandi, 2012
Iran (Hormozgan Pro.)	Total	Both	0.68	3.65	2.5	1.15	4.08	0.93	115	Kamali *et al*., 2003
Iran (Hormozgan Pro.)	Total	Both	0.40	1.11	0.44	0.67	3.71	0.41	111	Taghavi motlgh 2010; Taghavi motlagh and
Iran (Oman Sea)	Total	Both	0.85	4.37	3.52	0.67	4.18	0.5	176	Present study, 2018

According to King (2007), in different locations, the differences in length and growth factors are affected by the ecological differences of each area. In general, the differences in the asymptotic length (L∞) and growth coefficient (k) from one region to another can be due to the quantity and quality of food and weather conditions (Bartulovic *et al*., 2004).

Growth performance index (Φ) was found to be 4.18, in the range of 3.72-4.08 that reported in others researches (Table 3). Maximum age (Tmax) for *T. lepturus* was found to be 6 years by using the Pauly and Froese (2012) formula (Tmax = t0 +3/K). Absorbed energy is used for body maintenance, activity, reproduction, and less than 1/3 for growth.

The result of exploitation rate revealed that there is pressure on hairtail stock in north waters of the Oman Sea. According to Gulland (1971, 1979), the yield is optimized when F=M (or Fmsy=M (Parger, 1994; NMFS, 1996)) and U is lower than 0.5. These findings are valuable for fisheries management specialists as they warn that the fish resource is overexploited, therefore, a considerable decrease in fishing effort would be needed in case of management aims to become attained.

We Check out the maximum sustainable yield (MSY=15390 t) and catch (Y=17162 t) of this species in 2017. The estimated stock status shows that *T. lepturus* stock were overfished (Y>MSY). However, the existing fishing mortality rate (3.52 year^{-1}) was greater than that which would maximize yield per recruit at the existing size at first capture, clearly demonstrate that growth overfishing is occurring for this species (Fig. 6). The relative biomass per recruit at the estimated fishing mortality rate was particularly low at less than 10% of the unexploited level. Pauly and Soriano (1986) predicted the effects of increasing the existing mean size at first capture (*L*50=77 cm) at which yield per recruit would be maximized. Evaluations of resource status were made using estimates of exploitation rates associated with: a marginal increase of relative yield per recruit, which is of its value at maximum sustainable yield (*E*max).

In conclusion, the biological reference points estimated in this study could provide scientific background for the management of the largehead hairtail fishery, and any increase in the existing fishing level/exploitation would most likely result in a reduction in the yield per recruit and thereby hamper the optimum level. It is necessary to impose fishing regulation on the stock and this could be done by gradually increasing the mesh size of the gears or by restricting fishing seasons or declaring fish sanctuaries in the spawning grounds.

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