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Research Article

Estimation of fisheries reference points of the Largehead hairtail, *Trichiurus lepturus* (Teleostei: Trichiuridae) in Iranian waters of Persian Gulf and Oman Sea

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Abstract: The purpose of this study was to develop a framework to investigate the catch trend and estimation of the optimized catch limit of the Largehead hairtail, *Trichiurus lepturus*, stock by collecting catch data in the Iranian part of Persian Gulf and Oman Sea. In this research, catch data was collected for 20 years (1997-2018) and the optimized catch limit was estimated using data-limited approach and R Software. The average catch (Ct) for this period was 11550 tonnes (95% confidence interval 11500-11599 tonnes) and it has significantly increased over the past two decades (R=0.68, $P<0.05$). The intrinsic growth rate (r), carrying capacity (K), maximum sustainable yield (MSY), biomass of maximum sustainable yield (Bmsy), current biomass (B), fishing mortality of maximum sustainable yield (Fmsy) and present fishing mortality (F) were obtained by Catch-maximum sustainable yield (CMSY) models. The results showed that stock of the Largehead hairtail is suffering from over fishing and thereby, reduction of the fishing mortality and exploitation rate and bring back them to the MSY level are essential to save the stock.

Keywords: Fisheries Management, Catch- maximum sustainable yield (CMSY), Iranian Waters.

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Introduction

The world fisheries production was estimated 91 million tonnes, with 87% in seawater (79.3 million tonnes) and 13% in inland water (11.6 million tonnes) in 2016 (FAO 2018). In recent years, there have been significant signs of an over-fishing and unreasonable harvest of major fish stocks and other aquatic species, including serious damage to aquatic ecosystems and economic losses parallel to fisheries activities (FAO 2018). According to Food and Agriculture Organization of the United Nations (FAO) studies, the proportion of Biologically Sustainable Levels (BSLs) to Biologically Unsustainable Levels (BULs) in 1974 was about 90 percent and reached 67 percent in 2016, thus increasing unsustainable aquatic ecosystems requires immediate management measures (FAO 2018).

Largehead hairtail/Ribbonfish, *Trichiurus lepturus* Linnaeus, 1758. belongs to Perciformes Order and Trichiuridae family, that are available in marine and brackish water environments (Riede 2004) and usually live at depths of 100 to 350m (Muus & Nielsen 1999) and latitudes 49 degrees north and 54 degrees southern (tropical and subtropical and also temperate species) and prefer the temperature of 10 to 23°C (Kaschner et al. 2016). They have a daily feed migration in both adults and immature and they are generally found in coastal areas and mud beds (Nakamura 1995). This species has commercial value and its catch has increased in recent years and had risen from 7,000 tonnes in 1998 to more than 55,000 tonnes in 2018 (Fisheries

Statistical Yearbook, Iranian Area. 2018). It is the 12th largest species in the world fisheries production, and more than 1265,000 tonnes had been caught in 2015. *Trichiurus lepturus* is a Carnivore with strong cannibalistic behavior. Fin fishes were the most preffered prey group in the diet of this species followed by Crustacean and Cephalopods (FAO 2017).

The Persian Gulf and Oman Sea, with its unique ecological conditions, host a wide variety of aquatic species that provide livelihood, employment and vast economic activities for the settlers (Taghavimotlagh & Shojaei 2017). Iran has more than 120,000 fishermen, whose main job is fishing, and fishing has played a major role in creating employment in coastal areas, as well as in economic activities for post-harvest operations (Taghavimotlagh 2010).

Despite the economic importance of this species, little is known about the assessment of this fish. Different aspects of biological work of Large head hairtail have been done by different authors (Kamali 2005.; Taghavimotlagh 2010; Taghavimotlagh & Shojaei 2017) but no work has been done on stock assessment of this species in Iran. Fisheries Reference Points (FRP) are one of the most important issues affecting fisheries management, and for many of the world's fisheries stocks, their exploitation and stock status are unknown (Froese et al. 2012). The present study is the first step to investigate fishing trends for this species in Southern Iranian waters with the aim of identifying fisheries reference points and optimal fishing range of this species stock.

Fig.1. Large head hairtail (*Trichiurus lepturus*) in the Persian Gulf and Oman Sea.

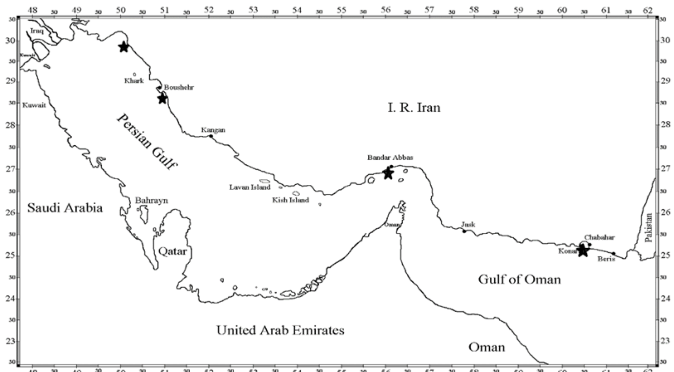

Fig.2. Location of landing sites for Largehead hairtail in the Persian Gulf and Oman Sea.

Materials and Methods

Landing Data (tonnes) of large head hairtail was collected by the Iranian Fisheries Organization (from 1997 to 2018) in 4 sampling sites (Persian Gulf and Oman Sea) for the last two decades (Fig. 1). These stations in South Waters of Iran were: Khuzestan (49˚70΄E, 30˚23΄N), Boushehr (51˚51΄E, 28˚76΄N), Hormozgan (56˚26΄E, 27˚18΄N) and Sistan & Baluchistan (60˚64΄E, 25˚29΄N). (Fig. 2)

Catch-MSY (CMSY): The Catch-MSY model has the same characteristics as the Graham-Shaefer surplus production model. These models rely on only a catch time series dataset and prior ranges of r and k and possible ranges of stock sizes in the first and final years of the time series. The CMSY is a method for estimating maximum sustainable yield (MSY) and related fisheries reference points (Bmsy, Fmsy) from catch data and information on resilience (Froese et al. 2017). This model requires a prior distribution on r and K as well as priors on the relative proportion of biomass at the beginning (Martell & Froese 2013). The biomass in subsequent years was then generated from a Schaefer model according to Equation:

$$B_{y+1} = B_y + rB_y\,(1 - B_y/k)\,es^1 - Ct\,es^2$$

Where By=Biomass in the year y+1, r= population instantaneous growth rate, K=carrying capacity, Cy =catch in the time series. In this method, the values of population instantaneous growth rate and carrying

Table 1. Comparison of different indices of CMSY models for Largehead hairtail in the Persian Gulf and Oman Sea.

Indices / models	CMSY Average (Maximum-minimum)
Biomass (1000 tonnes)	88.4 (42-100)
MSY (1000 tonnes)	30.7 (18.9-49.9)
Bmsy (1000 tonnes)	51.5 (32-82)
Fmsy	0.59 (0.47-0.74)
B/Bmsy	1.12 (1.94-0.8)
F/Fmsy	1.63 (1.24-2.24)
K (1000 tonnes)	103 (64.6-164)
B/K	0.85
r	1.19 (0.95-1.48)
F	0.17 (0.02-0.94)

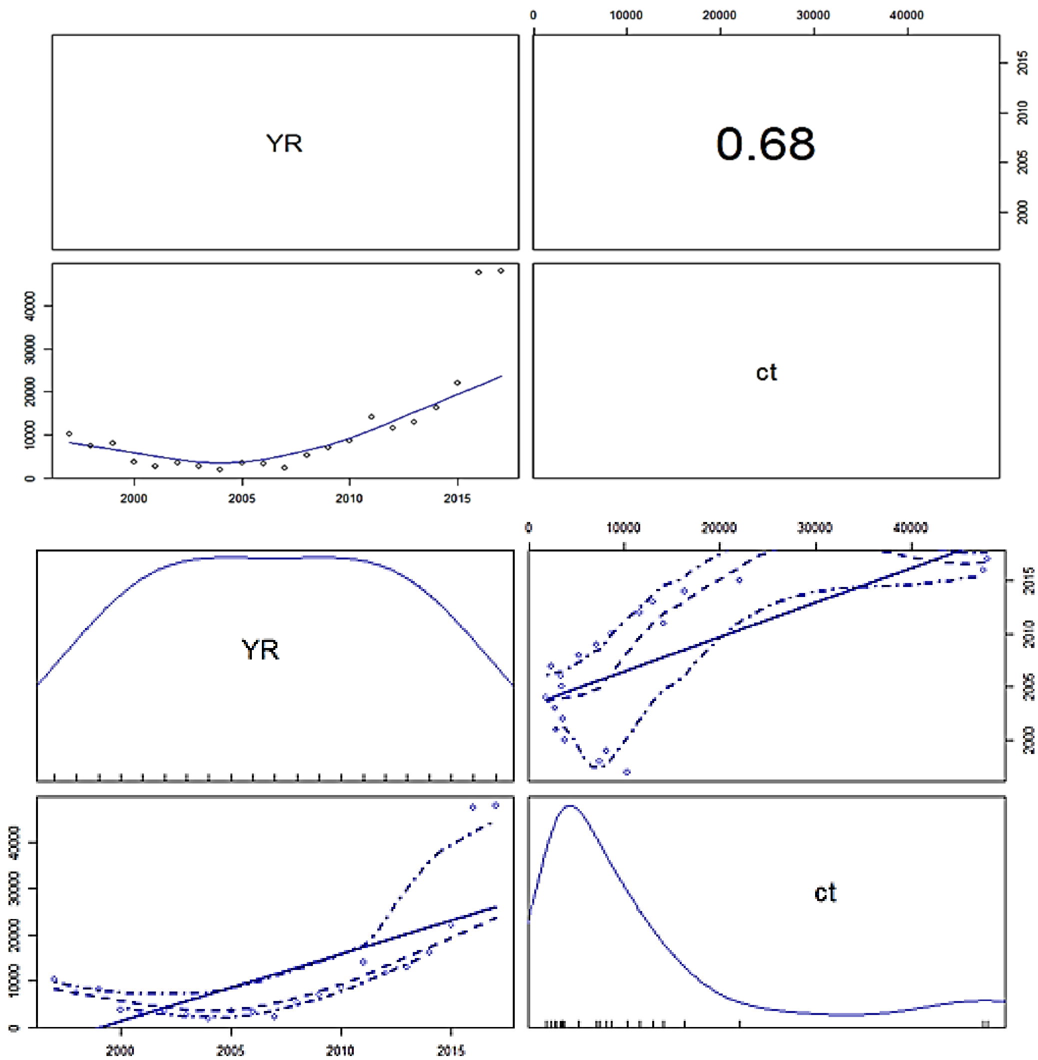

Fig.3. Changes of annual (yr) catch (Ct) trend for Largehead hairtail in the Persian Gulf and Oman Sea.

capacity are calculated with depletion formula (d) and storage saturation (S): d=1-S = 1-By / Ky. The maximum steady-state mortality rate with the aid of formula Fmsy=r / 2 and the maximum sustainable

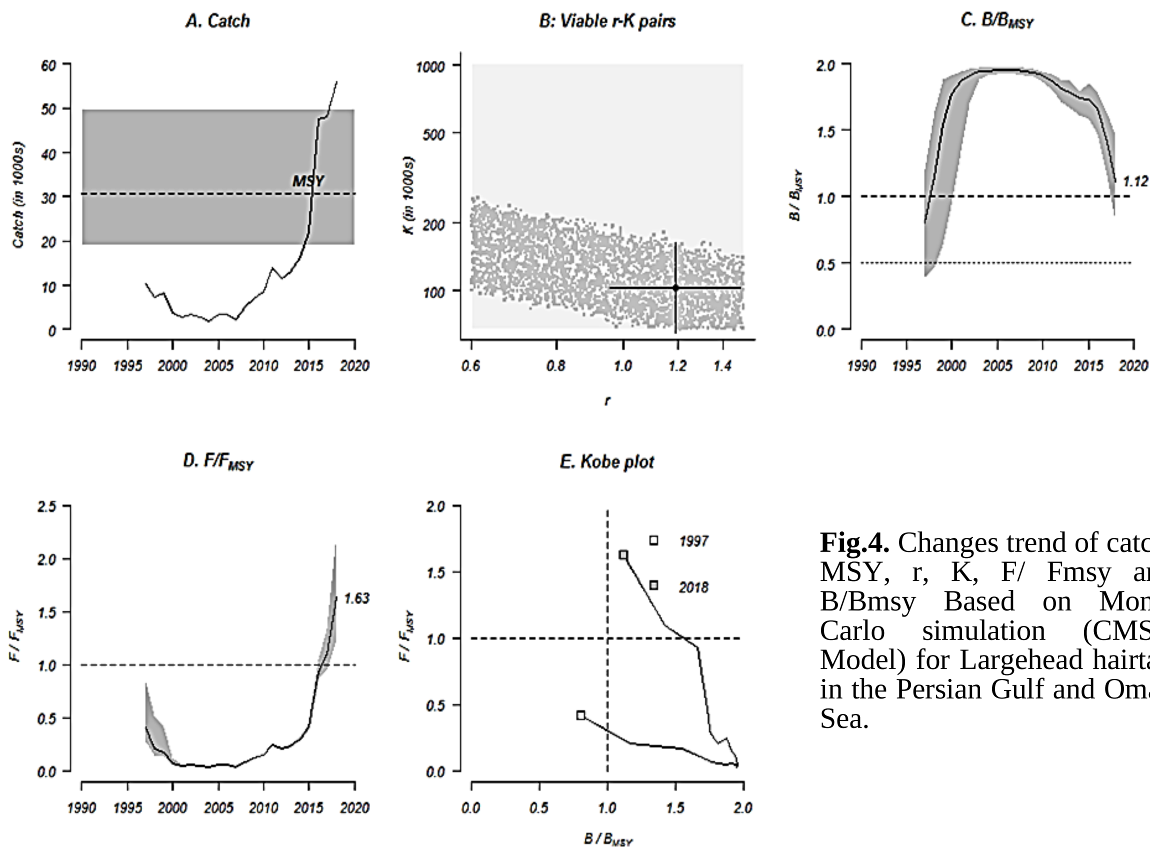

Fig.4. Changes trend of catch, MSY, r, K, F/ Fmsy and B/Bmsy Based on Monte Carlo simulation (CMSY Model) for Largehead hairtail in the Persian Gulf and Oman Sea.

yield is calculated from MSY=rk / 4 and Bmsy=K / 2 (Zhou et al. 2017). es[1] and es[2] is related to process error and observation error, respectively.

A prior range was set for r based on the resilience of the stock as proposed by Martell & Froese (2013), where stocks with a high resiliency were allocated an r value from 0.6–1.5. Largehead hairtail, according to Taghavimotlagh (2010) and Taghavimotlagh & Shojaei (2017) studies has a high level of resilience in this local. The rule of thumb of r=2FMSY=2M is a prevailing assumption when population dynamics are evaluated by the Schaefer surplus production model (Quinn & Deriso 1990). Statistical analysis was performed using an R package "Catch-MSY", R studio (1.1.446) software and SPSS (21), and the significance level was 0.05 and the confidence interval was 95%.

Results

The average catch (Ct) for this period (from 1997 to 2018 year) was 11550 tonnes (95% confidence interval 11500-11599 tonnes) and average catch (R = 0.68, P<0.05) had significantly increased over the past two decades. In this research, the initial intrinsic growth rate (r) and initial relative biomass (B) was 0.6-1.2 and 0.5-0.9, respectively. The output values of the model after 30000 Monte Carlo simulations were obtained as follows.

The average (maximum-minimum) of the population instantaneous growth rate (r), carrying capacity (K), maximum sustainable yield (MSY), biomass of maximum sustainable yield (Bmsy), current biomass (B), fishing mortality of maximum sustainable yield (Fmsy) and present fishing mortality (F) were obtained by Catch- maximum sustainable yield (CMSY) models (Fig. 3, Table 1). The biomass (B) to biomass of the maximum sustainable yield (Bmsy) ratio (B / Bmsy) and the mortality fishing (F) to mortality fishing of the maximum sustainable yield (Fmsy) ratio (F / Fmsy) in the CMSY model were 1.12 and 1.63 (in 2018 year). The (B / Bmsy) ratio and (F / Fmsy) ratio showed a decreasing trend and increasing trend, respectively (Fig. 4).

Discussion

Largehead hairtail have been heavily expolited in Southern Iranian waters due to their export value in recent years. Over the past two decades, the catch rates of this species in the southern waters had risen to more than 55,000 tonnes in 2018, indicating a sharp increase in this trend (Fisheries Statistical Yearbook, Iranian Area. 2018). The catches percentage of this species in compare to the total catch and demersal catch in Iran were about 4 and 7% in 1997, respectively. In 2018, this percentage of total catch and demersal catch arrived more than 7 and 21%, respectively (Fisheries Statistical Yearbook, Iranian Area 2018).

Several studies have shown that there is no significant difference between the estimations of the CMSY and the Bayesian state-space surplus production model (BSM) model, and some of them have been reported the similarity of 90% of these two models (Froese et al. 2016). One of the most important reasons for this is the similarity in the initial input values of the population instantaneous growth rate (r) of the species (Froese et al. 2016). Also, where CPUE was available instead of biomass, it showed that BSM and CMSY estimations of r, k, and MSY were not significantly distingushed in 89% of the stocks (Palomares & Froese, 2017).

The population instantaneous growth rate (r) is one of the important parameters in the modeling and fisheries management for determining the population growth, the ability to withstand the catch pressure and the recovery and renewal of the population (Zhou et al. 2016). It is necessary to determine the limits of this parameter (Froese & Pauly 2015). The different species divided with the population instantaneous growth rate (r) values of 0.5-1.5 (high flexibility), 0.2-0.1 (moderate flexibility), 0.5-0.5 (low flexibility) and 0.1 - 0.015 (very low flexibility) (Martell & Froese 2013; Froese et al. 2016). Between this parameter (r) and other life history parameters is a significant relationship. For example, between natural mortality (M) and this parameter (r) relashianship was reported in bony fish r=1.73 M and in cartilage fish r=0.76 M (Zhou et al. 2016). In Froese & Pauly (2015) studies, the parameter r is approximately equal with 2 Fmsy, 2 natural mortality (M), 3 Growth parameter (3 K), 3 divided by generation time (tgen) and 9 divided by maximum age (tmax) ($r \approx 2\ Fmsy \approx 2M \approx 3K \approx 3/tgen \approx 9\ /\ tmax$).

The species status in the southern Iranian waters, based on B / Bmsy, is fully exploited and based on F / FMSY which indicated over-fishing (Arrizabalaga et al. 2012) and also current catch is higher than the maximum catch of this species. The fishing situation is usually assessed on the basis of B / Bmsy and it is divided into three parts: The value of B / Bmsy greater than or equal to 1.5 (less than optimal fishing status), between 1.5 and 0.5 (full exploited status) and between 0.5 and 0.2 (overexploited status) and values Less than 0.2 (collapsed status) (Branch et al. 2011; Anderson et al. 2012).

One of the important indicators of Biological Reference Points (BRP) is the biomass of the maximum sustainable yield to carry capacity or stock status (Bmsy / K), and this indicator in this species is showed near 49% (or 0.49), that represents the Medium (0.2-0.6) depletion rate (Palomares & Froese 2017). Generally, the optimal proportion of this ratio varies from species to species, and is usually between 30 and 60%. Fish species with higher population intrinsic growth rates has less rates of Bmsy / K (also vice versa). Ultimately this index is considered to be between 30 and 20%, and less than this value shows a sharp decrease in fish stock (Gabriel & Mace 1999). Undoubtedly, the exploitation rate and population biomass change with population intrinsic growth rates and affects the rate of Bmsy / K ratio (Zhou et al. 2016). This research shows that the annual harvest (about 55 thousand tonnes in 2018) exceeds the maximum sustainable yield of this species in South Waters of Iran, and decrease exploitation ratio and fishing effort are proposed.

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مقاله پژوهشی

برآورد نقاط مرجع شیلاتی ماهی یال‌اسبی سر بزرگ (*Trichiurus lepturus* Linnaeus, 1758) در آب‌های ایرانی خلیج فارس و دریای عمان

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چکیده: هدف از این مطالعه، توسعه چارچوبی به منظور بررسی روند صید و برآورد محدود صید بهینه ذخیره ماهی یال اسبی سر بزرگ (*Trichiurus lepturus*) با جمع‌آوری داده‌های صید در بخش ایرانی خلیج فارس و دریای عمان می‌باشد. در این تحقیق، داده‌های صید برای ۲۰ سال (۲۰۱۷-۱۹۹۷) جمع‌آوری و حد مجاز صید با استفاده ازرویکرد داده‌های محدود در نرم‌افزار R برآورد شد. میانگین صید (Ct) برای این دوره ۱۱۵۵۰ تن (با فاصله اطمینان ۹۵٪ ۱۱۵۰۰ تا۱۱۵۹۹ تن) بوده و طی دو دهه گذشته به‌طور قابل توجهی افزایش یافته است ($R=0.68$, $P<۰/۰۵$). میانگین (حداکثر-حداقل) نرخ رشد آنی (r)، ظرفیت حمل (K)، حداکثر محصول پایدار (MSY)، زیست توده حداکثر محصول پایدار (Bmsy)، زیست توده فعلی (B)، مرگ و میر ماهیگیری با حداکثر محصول پایدار (Fmsy) و مرگ و میر ماهیگیری موجود (F) با استفاده از مدل صید محصول حداکثر پایدار (Cmsy) به دست آمد. نتایج نشان داد که ذخیره ماهی یال اسبی سربزرگ از صید بی رویه آسیب دیده و بنابراین کاهش مرگ و میر صیادی و نرخ بهره برداری و برگشت به سطح حداکثر محصول پایدار (MSY) جهت حفظ ذخیره، ضروری می‌باشد.

کلمات‌کلیدی: مدیریت صیادی، صید- محصول حداکثر پایدار (CMSY)، آب‌های ایران.