A Synoptic Review of the Biological & Population Dynamic Parameter Studies on Longtail tuna (*Thunnus tonggol*) in the Persian Gulf & Oman Sea

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Abstract:

Research studies on longtail tuna has been initiated in nineties in the Persian Gulf & Oman Sea. A synoptic review of the different research studies including size frequencies, length-weight relationship, growth and mortality parameters, biological studies, distribution pattern, stock structure, stock assessment, biological reference points, and management advice were reviewed , discussed and reported.

Introduction:

Tuna support some of the largest and most valuable fisheries in the world, but also provide food security for many developing and developed nations (FAO, 2018). Over half of the global tuna catch is derived from the western and central Pacific Ocean (WCPO) and the Indian Ocean, primarily comprising skipjack, yellowfin, bigeye, and albacore tunas. The populations of some of these species are approaching full utilization, particularly in the Indian Ocean (e.g. Langley 2015). However, increasing market demands for seafood, national food security issues have led to increased targeting, or at least retention, of smaller tuna species in neritic waters, including longtail tuna *Thunnus tonggol* (Bleeker, 1851). Longtail tuna is a tropical and subtropical species whose geographical range extends from the Western Pacific Ocean to the Western Indian Ocean. It occurs from the coasts of Japan through the Philippines and Indonesia to Papua New Guinea, and from the sub-tropical east and west coasts of Australia northwest through Malaysia and Thailand to India, Sri Lanka, and Pakistan, and finally to the Persian Gulf and the Red Sea. A distinctive characteristic of longtail tuna is that it is not considered to be a highly migratory species (Willette,

2019) and is instead a more neritic or coastal species. Longtail tuna is the second smallest *Thunnus* species, which is found throughout tropical and subtropical neritic waters of the Indo-Pacific. Because of their nearshore distribution, longtail tuna are caught in large- and small-scale commercial, artisanal, and recreational multispecies fisheries of many developing and developed coastal nations. In the Indo-Pacific region, longtail tuna has become a particularly important species for developing states, with the global catch more than tripling from 96,276 tons in 1997 to 297,702 tons in 2007 and continuing to exceed 211,000 tons annually (FAO, 2020). Over the average catches of five years (2015-19) in the Indian Ocean ,42% of the catches of longtail are accounted for by I.R. Iran, followed by Indonesia (~19%), Sultanate of Oman (~12%), and Pakistan (~11%) (IOTC-2021-SC24-ES09).

Length frequencies:

The average length of the fish was estimated 74±11.2cm in 2006-07. The minimum and maximum of the length were observed in 26 and 125cm, respectively. Most of the individuals were found between 77 to 80 cm. (Kaymaram et al., 2013). Among the 4383 specimens of *T.tonggol* collected during 2015-16, dominant size frequency was from 25 to 124 cm FLwith mean 71 cm (Darvishi et al., 2018).

Length weight relationship:

The parameters of the length-weight relationship $W = a L^b$ were calculated in 2006-07, after linear transformation and regression analysis. Length-weight relationship was determined, as $W=0.00002 L^{2.84}$ .The regression coefficient b was not significantly different from (b=3), in which shows the isometric growth ($p>0.05$) (Kaymaram et al., 2013) (Table.1).

The weight and length pairs data of 331 longtail tuna were obtained in the Persian Gulf & Oman Sea in 2015-16 and length-weight relationship was: TW=0.00002 FL $^{2.87}$(R^2=0.97) (Darvishi et al.,2018).

Table .1 .Summary of length- weight relationship parameters on longtail tuna in the IOTC area

Authors	Area	Base of length	a	b
James *et al.*, 1993	India	TL	0.000083	2.71
Khorshidian &carrara,1993	Iran	FL	0.0015	2.43
Griffiths *et al.*,2011	Australia	FL	0.00005	2.82
Darvishi *et al.*,2003	Iran	FL	0.00004	2.7

Growth parameters:

The observed extreme fork length was 125 cm in 2006-07. The range of 95 % confidence interval for extreme fork length was 122.11-142.49 cm (Table.2) .Estimated length infinity was 133.7 cm that was based upon the largest fork length in each sampled month. The growth coefficient (K) was calculated by scan of K value as 0.35 per year (Kaymaram et al., 2011)

Table 2. Summary of growth studies on Longtail tuna in IOTC area

Author	Area	Length infinity ,(cm)	Growth coefficient, (per year)
Prabhakar&Dudley,1989	Omani Waters	133.6	0.23

Wilson, 1981	Gulf of Papua	122.9	0.41
Silas et al.,1986	Indian Waters	93	0.49
Griffiths et al.,2010	Central Indo Pacific	135.4	0.22
Kaymaram et al.,2013	P.G & O.S*	133.7	0.35
Darvishi et al.,2018	Persian Gulf	129.6	0.39
Hashemi et al.,2021	P.G & O.S	137	0.41

* Persian Gulf & Oman Sea

Growth parameters were computed as L_∞=129.6 cm, K=0.39 year-1 and $t_0=-0.28$ with the growth performance index, ϕ' of 8.7 in the Persian Gulf & Oman Sea in 2015-16 (Darvishi et al., 2018) (Table. 2).

Mortality parameters:

Z/K and length infinity were estimated in the Persian Gulf & Oman Sea in 2006-07 by Powell-Wetherall plot 5.2 and 133.79 cm respectively. The natural mortality coefficient "M" was estimated as 0.55 by employing the equation of Pauly, where mean sea surface temperature considered in this study as 26.5^{oc}. As the pelagic species grow to a large size very fast, the "M" value may be an over-estimation. Hence, the value was multiplied by 0.8 to get a revised estimate of "M" as 0.44.

F=Z-M= 1.82-0.44=1.38

The exploitation rate of Longtail tuna was estimated 0.75 (Kaymaram et al., 2013).

The natural mortality of Longtail tuna (M) of 0.44 is in line with estimate obtained in 1992-93 as 0.49 in the same area (Khorshidian & Carrara, 1993). These two estimates through the Pauly's formula appears to be very low when compared to natural mortality of 0.8 per year obtained in Indian waters by James et al., 1993.

The total mortality obtained in this study seems to be under estimated in comparison with other studies such as 3.84 reported in Gulf of Thailand by Supongpan & Saikliang, 1987 and 3.13 by Khorshidian & Carrara, 1993.

Fishery, biology, and population characteristics of the longtail tuna were studied during 2006-10.There is no targeted exploitation of this species in the Indian Waters and mainly landed as by catch of gill net fishery. Natural mortality (M), total mortality (Z) and fishing mortality (F) were estimated 0.77 y^{-1}, 3.72 y^{-1} and 2.94 y^{-1}, respectively. Spawning stock biomass formed 65.4% of the standing stock. Study indicates scope for improving production of the species (Abdussamad et al., 2012).

Biological studies:

Longtail tuna is found in water temperatures ranging from 16° to 31°C. While juveniles and young adults are primarily found in water temperatures of 24-28°C at equatorial and tropical latitudes, larger adults prefer cooler subtropical waters (18-22°C) (Willette, 2019).

Spawning probably takes place in two seasons in the northern hemisphere (between March-May and July–December) and in a single period that extends from October to April in the southern hemisphere (Griffiths et al., 2019). It takes place in coastal regions at surface water temperatures of at least 28°C.

The species is non-selective in feeding and feed on pelagic finfishes, crabs, and cephalopods. Their size at maturity (Lm) is 51.1 cm and spawns round the year with major peak during October-November (Abdussamad et al., 2012).

Major spawning time was determined in summer with peak in August in the Persian Gulf & Oman Sea in 1997-98 (Darvishi et al., 2003). Analysis of stomach contents of longtail tuna was revealed that sardines, anchovies, small digested bony fishes, and squid were found in the specimens (Darvishi et al., 2003).

Distribution pattern:

Distribution pattern of longtail tuna was modeled based on satellite images and environmental data. Redundancy analysis and Generalized Additive Models (GAMs) to provide a preliminary view of relationships between LOT presence and environmental variables such as Sea-surface height (SSH), Chl a, Sea surface current velocity, Sea surface salinity (SSS) and Sea surface temperature (SST) (Vahabnezhad et al.,2021).

The data were collected 2015-19 by monthly bases, from Iranian tuna purse seiners in the Oman Sea. In this study, the annual and seasonal variation of longtail tuna CPUE has been investigated.

The results show that the spatial factor (Latitude) had a great influence on the presence of LOT within the range of 23°-25°N, the probability of presence increased as latitude increased.

Among the independent factors (SST, Chl a, SSS, SSH, and Current Velocity), SSTwas the most important influencing factor in the range of 25 to 33°C, and the deviance explained by GAM increased significantly after SST was added to the model. On the other hand, the probability of the presence of LOT increased when sea surface current Velocity was in the range of 64 to 89 cm/s and SSS in the range of 35.9 to 36.1 psu.

These results indicate that Chl a and SSH have a limited effect on the probability of the presence of longtail tuna. Latitude 23°-25°N and longitude 57°E to 60°E are the preferred habitats of *T. tonggol* in the Oman Sea (Vahabnezhad et al.,2021).

Another study tried to find out the association between the most important satellites derived environmental variables with longtail tuna catch of Iranian purse seiners in 2007-17 by applying Generalized Additive Model (GAM) in the southern waters of Iran. Results indicated the relatively high importance of temporal (month of fishing), spatial (latitude), and three environmental variables as Sea surface salinity (SSS), mixed layer depth (MLD), and Sea surface temperature (SST) (Haghi Vayghan et al., 2020).

Stock assessment:

The nominal catch time series dataset, which was available from 1950–2013 were extracted from the IOTC Secretariat database. Total catches of longtail tuna were decreased between 2012 and 2013 from 170 000 to 159 000 t, catches are still well above the estimated level of MSY. This is reflected in the key management reference points, which are also similar between two models (Catch-MSY method & Optimized Catch Only Method). The stock is likely to be subject to overfishing with an F_{2013}/F_{MSY} ratio of 1.23 and 1.11 for the Catch-MSY and OCOM models respectively (Martin & Shamra, 2015). These estimates also correspond well to those of the previous assessments in 2014, which were 1.08 and 1.23 (Zhou & Sharma, 2014).

Nominal catch data were extracted from the IOTC Secretariat database for the period 1950 - 2014, Results suggest that the stock is still likely to be subject to overfishing with an F_{2014}/F_{MSY} ratio of 1.07 and 1.03 for the Catch-MSY and OCOM models respectively. This ratio is slightly lower than estimated in previous years, reflecting the drop in catches reported in the last two years, suggesting that fishing mortality has declined (Martin & Robinson, 2016).

Nominal catch data of longtail were extracted from the IOTC Secretariat database for the period 1950 – 2015. C-MSY, OCOM and stochastic SRA, provided relatively similar estimates of MSY, with mean estimates of approx. 144 000 t, 140 000 t and 130 000 t respectively, with the highest estimate produced by the C-MSY method. The estimates produced by the C-MSY and OCOM methods are also similar to previous assessment estimates. Reported catches decreased between 2012 and 2015 from 175 459 to 136 856 t, and so the current catch is below the C-MSY and OCOM estimates of MSY, but remains above the stochastic SRA estimate. Results suggest that the stock is still likely to be subject to overfishing with all models producing a F_{2015}/F_{MSY} ratio above 1.00. This ratio has been decreasing over the last few years, reflecting the recent decline in catches. Nevertheless, estimates of the B_{2015} /B_{MSY} ratio have remained similar, given that the average catches over the last 5 years (157 000 t) have been higher than all estimates of MSY. These stock status predictions across the three models suggest that the stock is considered to be ‘subject to overfishing’ and the C-MSY and OCOM models suggest it is also ‘overfished’ while the stochastic SRA suggests it is ‘not overfished’(Martin & Fu, 2017).

Catch and effort data from the Iranian gillnet fishery in the coastal waters of Persian Gulf and Oman sea were analyzed , and applied statistical models to obtain abundance indices from nominal catch per unit effort (CPUE) for the main neritic tuna species captured in the fishery. The spatial and temporal trend of catch and effort was characterized, and standardization analysis using GLM models was conducted for longtail tuna (*T. tonggol*) using trip-level catch effort data collected from the port-sampling program from 2008 to 2017.The analyses showed that the standardized catch rates have declined for the longtail tuna (Fu et al.,2019) .

Stock structure:

There is great uncertainty regarding the stock structure of longtail tuna throughout their geographic range. For many years, it was thought that separate stocks might exist in different regions due to morphological differences in specimens caught in different areas. The genetic studies carried out by Kunal et al. (2014) in Indian waters and Willette et al. (2016) in the South China Sea concluded that longtail tuna exist as a single stock within their respective study regions; in comparing both studies (Willette et al., 2016), however, they found that fish from the South China Sea and Indian waters comprise two distinct stocks. On the other hand, some analyses mainly based on length-frequency data along Indian and Australian waters suggest that longtail tuna may exist as a single stock throughout Southeast Asia and Oceania, although the possibility of separate stocks being present in these regions cannot be dismissed (Griffiths et al., 2019). In another recent study, Griffiths et al. (2020) even suggested the possible existence of at least four main putative stocks: Oceania, Southeast Asia, western Indian Ocean, and eastern Indian Ocean. This knowledge gap on stock structures is one of the factors that have complicated accurate stock assessments.

In 2017, CSIRO (Australia) in collaboration with AZTI Tecnalia (Spain), IRD (France) and RITF (Indonesia) commenced a 3-year collaborative project on tuna, billfish, and sharks of the Indian Ocean. The sample coverage for longtail tuna covers a reasonable proportion of the Indian Ocean range. Unfortunately, it was not possible to source samples from the NW and W parts of its range. A total of 316 longtail tuna samples from three Indian Ocean sampling regions were collected and samples from a Pacific outlier are being sought. A total of 298 samples were sequenced using DArTSeq and included in the preliminary analysis of population structure. The preliminary population analysis based on StockR indicates a strong preference for two or three genetic groupings within the Indian Ocean with three groups being most likely based on the model fits (Davies et al.,2019).

Biological Reference Points (BRPs):

Depletion-based stock reduction analysis (DBSRA) and Catch maximum sustainable yield (CMSY) models were used to estimate BRPs in the Persian Gulf & Oman Sea by applying data from 1997 to 2018.The B/B_{MSY} was calculated as smaller than 1.0 in both models, while F/F_{MSY} was mostly higher than 1.0, which indicates the overfishing of longtail tuna in the Persian Gulf & Oman Sea (Haghi Vayghan et al., 2021). Based on BRPs, it is recommended to implement an adjustment of annual harvest (around 55 thousand tons) as the simple (even quick) fisheries management strategies in order to guarantee the sustainable yield of this species in southern waters of Iran. We also recommend that catch-only methods could be treated as a temporary stepping-stone while sufficient data (e.g. size or age composition) is available for more reliable methods to be applied.

Management advice:

The catch in 2019 was below the estimated MSY but the exploitation rate has been increasing over the last few years, because of the declining abundance. Despite the substantial uncertainties, this suggests that the stock is very close to being fished at MSY levels and that higher catches may not be sustained. A precautionary approach to management is recommended.

The following should be also noted:

• The Maximum Sustainable Yield estimate of around 128,750 t was exceeded between 2011 and 2018. Limits to catches are warranted to recover the stock to the BMSY level.

• Limit reference points: The Commission has not adopted limit reference points for any of the neritic tunas under its mandate.

• Further work is needed to improve the reliability of the catch series. Reported catches should be verified or estimated, based on expert knowledge of the history of the various fisheries or through statistical extrapolation methods.

• Improvements in data collection and reporting are required if the stock is to be assessed using integrated stock assessment models.

• Research emphasis should be focused on collating catch per unit effort (CPUE) time series for the main fleets (I.R. Iran, Indonesia, Pakistan, Sultanate of Oman, and India), size compositions, and life trait history parameters (e.g., estimates of growth, natural mortality, maturity, etc.).

• There is limited information submitted by CPCs on total catches, catch and effort and size data for neritic tunas, despite their mandatory reporting status. In the case of 2020 catches (reference year 2019), 30% of the total catches were either fully or partially estimated by the IOTC Secretariat, which increases the uncertainty of the stock assessments using these data. Therefore, the management advice to the Commission includes the need for CPCs to comply with IOTC data requirements per Resolution 15/01 and 15/02.

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