Studies on some aspects of biology, population dynamics and proximate composition of *Thunnus tonggol* (Longtail Tuna) occurring in the North-West coast of Indian EEZ.

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Abstract

Studies on Length-weight relationship, age, growth, mortality parameters, food & feeding habits, maturity & spawning and proximate composition of longtail Tuna, *Thunnus tonggol* occurring along the north-west coast of Indian EEZ were attempted for the present research work. A total of 1214 specimens were collected from the major fish landing centers of Gujarat and Maharashtra, India during the period 2018 - 2022. The fork length of this species ranged between 22 and 86 cm, regression coefficient (b) is 2.65, and correlation coefficient 'r^2' is 0.9 indicating a high degree of correlation and better fit of the length-weight relationship. The asymptotic length ($L\infty$), Curvature parameter (K) of the VBGF are 98.65, 0.39 respectively and age at zero length (to) is -0.33 and the growth performance index (f) is 3.72. The natural mortality (M), fishing mortality (F) and total mortality rate for estimated at 0.73 year-1, 0.49 year-1 and 1.22 year-1 respectively. The gut content of longtail tuna is dominated with small pelagic fishes, particularly carangids, myctophids, anchovies, clupeids, crustaceans (mostly of *Acetes indicus)* and Cephalopods (only squids). In *T. tonggol*, the proportion of maturing females (stage III) was found to be high in Jan - March and decreased to the lowest levels in May-August and thereafter increased to the highest level in December. Matured females were found during January - April and also during August - September. Spent females were observed in January and February and again during April and May. This implies that there are two district spawning seasons for longtail tuna. The species *T. tonggol* attain maturity at 480 mm and the minimum size at maturity (50%) for females of *T. tonggol* reported at 240 mm F.L. The sex ratio (male to female) for *T. tonggol* was recorded found to be 1:1.3. The Gonado Somatic Index (GSI) values of females ranged from 0.042 to 0.573 in *T. tonggol*. The fecundity of *Thunnus tonggol* varies from 1,43,230 to 22,30,000. The proximate composition indicated the moisture content of 71.0%, protein (23.2%), lipid (4.2%), glycogen (0.4%) and ash (1.4%). The results derived from this study would be helpful in deriving strategies for improving the exploitation of this species with a sustainable approach.

Keywords: Asymptotic length, Curvature parameter, Growth performance index, Natural mortality, Gonado-somatic Index.

Introduction

Global marine production was estimated at 91 million tonnes and Asia's contribution was 47,062 thousand tonnes. Among Asian countries, India's marine production was estimated to the tune of 5487 thousand tonnes (FAO Statistics 2022). India ranks 3rd in the marine capture fish production after China and Indonesia with 5.5 million tonnes forming 6% of the total production of the world. India has a coastline of 11098 km (Anon, 2025) and an EEZ of 2.02 million Km^2. There are 9 Coastal states and 4 Union territories along the coastline of India. The Indian Exclusive Economic Zone has been divided into 5 zones (regions) such as; North-west coast, South-west coast, North-east coast, South-east coast and Andaman & Nicobar coast. The marine fisheries potential was estimated at 5.31 million tonnes of which, only 3.65 million tonnes were harvested (Anon, 2018). In India, the marine capture fish production from the year 2018 to 2022 was estimated as 3.63, 3.69, 2.72, 3.17 and 3.65 million tonnes respectively.

The Neritic tunas in India are contributed by *Euthynnus affinis* (Little Tuna/Kawa Kawa), *Auxis thazard* (Frigate Tuna), *Auxis rochei* (Bullet Tuna), *Thunnus tonggol (*Longtail Tuna) and *Sarda orientalis* (Bonitos). The Neritic Tuna species are mostly harvested by traditional, motorized and mechanized boats with various fishing gears such as gillnets, hooks & lines and trawl nets operated along the continental shelf. Among the Neritic tunas, *Thunnus tonggol* was the third most dominant species with a contribution of 2756 tonnes in comparison to *Euthynnus affinis* and *Auxis sp*. with a catch of 45,260 tonnes and 20,111 tonnes respectively (CMFRI, 2022).

The species *Thunnus tonggol* (Longtail Tuna) belongs to the family Scombridae, one of the important neritic tuna species occurring in the North-west coast of the Indian EEZ. The contribution of Neritic Tunas during 2022 was 68127 tonnes forming 1.86% of the total marine fish production of the country. The contribution of the species *Thunnus tonggol* in the year 2022 was 2756 tonnes forming 4.05% of the total Neritic Tuna production (CMFRI, 2022).

The study of the dynamics of a fish population is an initial step to derive a relationship between the weight and length of a fish. The length-weight relationship of tuna species is an important factor in the biological study of fishes and their stock assessments. This relationship is helpful in estimating the weight of a fish at a given length. Pauly (1983) described methods to estimate the length-weight relationship of fishes. The length-weight relationship is also useful in comparing populations in space and time (Beverton and Holt, 1956). This relationship is particularly important in yield equations and in the estimation of stock size.

Growth studies in Indian waters are largely based on length frequency distribution because age determination from other conventional methods has been found to be more difficult. Determination of the Age and Growth of fish is of commercial importance and is significant which contributes to have an

understanding of the age class structure of the stock and the role played by various year classes in the fluctuations of the fishery.

The study of growth means the determination of the body size as a function of age. Growth parameters not only differ from species to species but also vary from stock to stock within the same species. The length frequency method is generally helpful in inferring the average growth rate in fishes. Length frequency analysis has been made easier and more reliable by several statistical tools. Von Bertalanffy (1938) growth equation has been developed and widely used in fisheries science for analysis of length composition in terms of the parameters of specified growth.

To understand the dynamics of the fish population, the spawning biology of fishes is very much essential. It has been recognized that maturation and spawning in fishes are useful in predicting the rate of recruitment in fish stocks (Brosset *et al.*, 2020). The fluctuations in recruitment depends to a large degree on the spawning habits, biology of tunas and qualifying size-specific parameters. The gonad studies are very much essential to understand the spawning biology of fishes. The female gonad is considered better for studying the spawning period than the male gonad. The size at first maturity is very much essential and can be used as an important tool for any fishery management.

The knowledge of food and feeding habits is of immense use in understanding a fish population in the ecology and its production potential. The availability of nutritious food is an important factor that plays a significant role in the survival of living organisms (Mudumala V., personal communication). Most of the fishes are highly adaptable in their feeding habits and utilize the most richly available food Lagler (1977). Qasim (1972) gave a critical appraisal of the existing knowledge of the food and feeding habits of some marine fishes from the Indian waters and suggested how best the problem of community nutrition could be attempted in determining the transfer of energy from one trophic level to the other.

Fish is considered as a rich protein diet. Tuna is an important food fish and its meat is highly nutritious and known for its protein, fat and amino acid contents (George, 1975). Presently, there is an increased awareness about healthy foods, of which, fish has been found accepted as a highly valued healthy food because of its significant nutritional qualities. Knowledge of biochemical constituents in fish is essential for adopting appropriate technology towards creating awareness of its food and value among consumers. This is for making value-added products for human consumption and for the development of processing industries. Major constituents in the fish tissues are Water, Protein, Lipid (fat or oil), Glycogen and Ash (minerals) are found to be more important in calculating dietary values. The analysis of these five constituents is referred to as proximate analysis (Love, 1970).

Considering the economic importance of Neritic tuna species in India, the present study has been undertaken along the North-west coast of the Indian EEZ in order to understand the fishery of the species *Thunnus tonggol* and also to know the population parameters such as length-weight relationship, age &

growth and mortality, biological aspects such as food & feeding and maturation & spawning and the proximate composition of the fish.

Monitoring of Neritic tuna species, production trends and the changes in population parameters and biological characteristics are crucial while deriving the strategies for harvesting at a sustainable level and to conserve and manage this Neritic tuna species. Based on the results derived from this study, the *Thunnus tonggol* species production could be increased and will be an important reference for further investigations.

Material and Methods:

The area chosen for this study is the North-Western Indian EEZ. The samples of *Thunnus tonggol* were collected from commercial fish landings at Porbandar, Gujarat, Sassoon Dock and Ferry Wharf, Mumbai, Maharashtra, during 2018-2022. A total of 1214 fish samples ranging from 22 cm to 86 cm were considered for this study. The length (fork length in cm) and weight (in gm) measurements were taken using the linear centimeter scale and High-precision electronic balance. After recording the length and weight, the fish samples were utilized for carrying out biological studies and assessing the proximate composition.

In order to understand the length-weight relationship the fork length was considered and data was used for the calculation of the statistical relationship between length and weight by using the formula W=aLb and accordingly logarithmic liner equation was drawn. The linear regression was derived by using Y = a + bx which is a best fitting equation. The length-weight relationship was estimated by adopting Le Cren (1951) formula.

The most frequently used method to determine the growth of tropical fishes is length frequency analysis. Based on monthly length frequency distributions growth parameters are estimated using the FISAT II Programme (Gayanilo *et al*... 2005). The data was grouped by monthly intervals which is the best fit for the model to reduce the sampling errors and the age and growth parameters were estimated by adopting Modal progression analysis and VBGF model was also used for the estimation of age & growth and derived the values of Lμ, K. The length at age (t0) was derived using Pauly (1971) method.

Pauly (1980,1984) method was used to estimate natural mortality (M) and total mortality (Z) by considering the mean temperature of 280 C. After obtaining these parameters the fishing mortality (F=Z-M) was derived.

Having estimated a set of parameters, to understand the reliability, the parameters are evaluated and compared to the growth studies. This "Phi Prime Test" (Munro and Pauly, 1983, Pauly and Munro, 1984) has gained wide application and the following formula has been applied Θ' (Phi Prime) = ln K + 2*ln Lμ.

The food and feeding habits of *Thunnus tonggol* were carried out from 652 samples. After taking the measurements of Fork length & Weight, the food items of each fish were recorded by dissecting the

stomach. Food items were identified and recorded as a group. Wherever identification of food was not possible owing to the advanced digestion, such items expressed as semi-digested matters. The total number, net weight and frequency of occurrence of prey items in the stomach of *Thunnus tonggol* was recorded during the period of gut content analysis.

Stomach content analysis methods described earlier by Pillay (1950), Natarajan & Jingran (1961), Bhargava (1999), Bachok *et al.*, (2004), Somvanshi (1976) as usual estimation of the status of the gut and occurrence methods were followed for the study.

Further, to study the maturation and spawning, a total of 652 samples of the species *Thunnus tonggol* were analyzed during the study period. The specimens were dissected to understand the colour, shape and size of the gonads in relation to the body cavity. To determine the spawning season percentage occurrence of maturity stages viz., inactive (Stage-I & II), Active (Stage-III) and ripe (Stage-IV, V & VI) Spent (Stage-VII), were plotted by months and pooled for one year. Ova-diameter frequencies were recorded to investigate spawning periodicity. Observation of maturity and spawning was carried out based on matured eggs in the ovary. Ovaries of the mature fishes of known length and weight were dissected out and weighed and then immersed in Gilson's solution (Simpson, 1951) for easy separation of ova and fecundity and ova diameter and were calculated as per Clark (1934). The Gonado Somatic Index (GSI) was calculated to understand the possible progression of maturation and spawning. Size at first maturity was calculated for females. The number of mature specimens (Stage-III to IV) were recorded in each length group and their percentage was calculated. The sex ratio was derived based on the proportions of sexes (males and females) represented in various sizes. Percentage in each length group was calculated and sex ratio was calculated.

Estimation of Moisture, Protein, Lipid, Glycogen and Ash content was carried out using AOAC (1975), Lowry (1951), Barns (1973) and AOAC (1970) methods are adopted respectively.

Results and Discussion

Length-weight relationship:

The Long tail tuna, *Thunnus tonggol* was found to be occurring along the entire coast of India, but abundance was found to be higher on the west coast of India compared to the east coast. The size of the samples of *Thunnus tonggol* was between 22 & 86 cm. The Statistical relationship between the length and weight was found to be W= 5.383x10-2FL2.65080 and the corresponding logarithmic regression equation was calculated as Log W = -1.2689618 + 2.65080 Log L. The correlation coefficient (r2) gives the value of the degree of association of two variables and the value of r^2 is 0.9668. The details are represented graphically in Fig. 1and the length frequency distribution is depicted in Fig.2.

The significance of the differences between the regression coefficients (b) was tested by the method of analysis of covariance. The 'b' value is near 3 in *Thunnus tonggol* species. The correlation coefficient

'r^2' value is 0.9, indicating a higher degree of correlation and a better fit of the length-weight relationship indicates isometric growth.

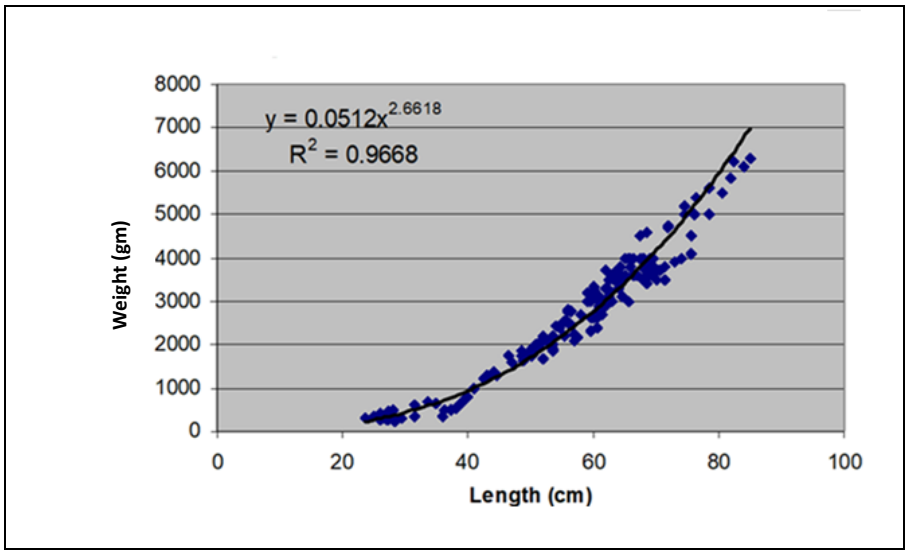

Fig. 1. Length-weight relationship of *Thunnus tonggol*

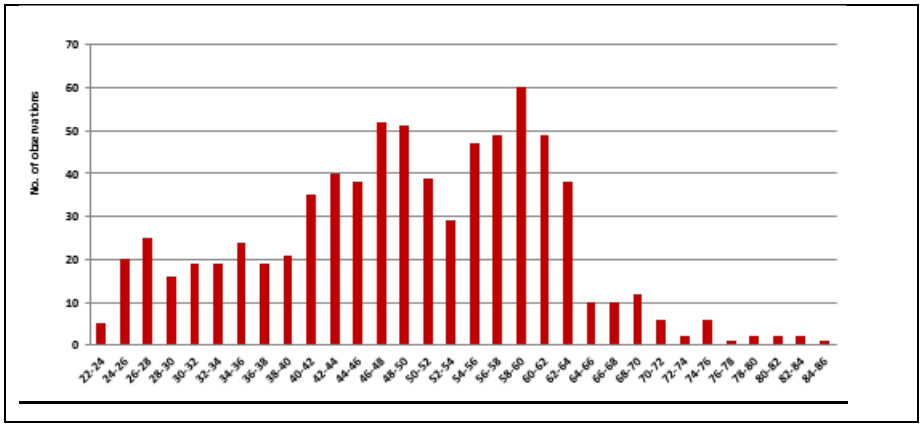

Fig. 2. Length frequency distribution of *T. tonggol*

Age and growth:

The growth parameters such as L∞ and K values derived in this present study are 98.65 and 0.39 respectively. After estimating a set of growth parameters to evaluate the reliability "Phi Prime test(f)" described by Munro and Pauly (1983) and Pauly and Munro (1984) has been applied and the values registered for *Thunnus tonggol* is 3.72. The length at age was determined using the VBGF (The 'age' fish would have had at length zero VBGF; it generally has a negative value but does not usually express "prenatal growth"). The values obtained for length at zero age (t_0) are 31 (1st year), 53 (2nd year),

68 (3rd year), 77(4th year) and 84 (5th year). The graphical representation of the same is presented in Figs 3 & 4.

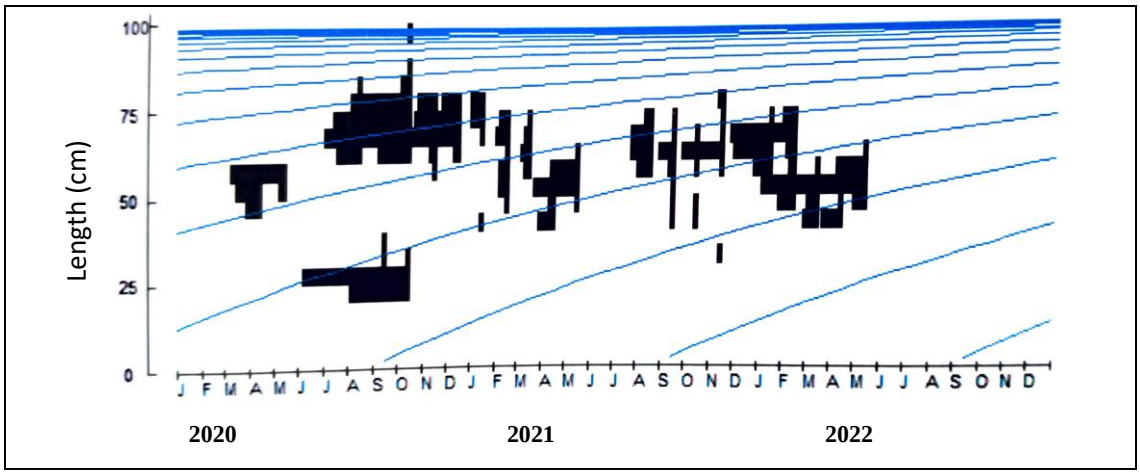

Fig. 3. Graphical representation of VBGF and length frequency plot for *Thunnus tonggol*

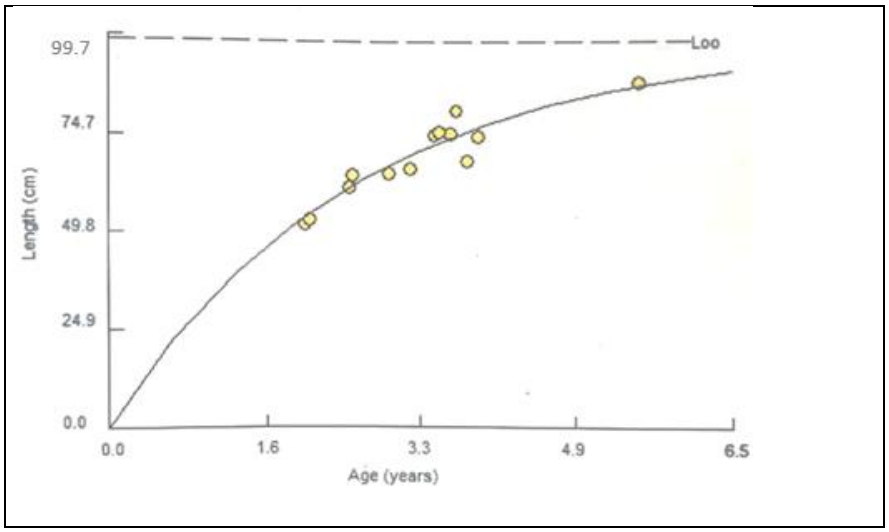

Fig. 4. Graphical representation of analysis of length at age for *Thunnus tonggol*

The values of natural mortality 'M' are computed by Pauly's empirical formula for the entire data collected for *Thunnus tonggol*. During the study, the estimated value of 'M' (natural mortality) is found to be 0.73, Z (total mortality) is 1.22 and F (fishing mortality) is 0.49. The growth parameter studies of *Thunnus tonggol* from several geographical areas including the present study, are presented in Table 1.

Table. 1. Growth parameters of Longtail tuna (*Thunnus tonggol*) from several geographical areas

Area	**L∞ (cm)**	**K (year-1)**	**t_0 (year-1)**	**Method**	**Source**
Papua New Guinea	122.9	0.41	-0.032	Length frequency	Wilson 1981a
India	93	0.49	-0.24	Length frequency	Silas *et. al.,* 1985
Thailand	58.2	1.44	-0.027	Length frequency	Supongpan & Saikliang 1987
Oman	133.6	0.228	-	Length frequency	Prabhakar & Dudley 1989
Thailand	108	0.55	-	Length frequency	Yesaki 1989
India	123.5	0.51	0.032	Length frequency	Abdussamad *et. al.,* 2012
Iran	133.8	0.35	-	Length frequency	Kaymaram *et. al.,* 2013
Pakistan	55.7	1.049	-	Length frequency	Ahmed *et. al.,* 2016
Iran	111.23	0.3	-0.38	Length frequency	Yasemi *et. al.,* 2017
Iran	129.6	0.39	-0.28	Length frequency	Darvishi *et. al.,* 2018
Java Sea	78.8	0.41	-0.048	Length frequency	Thomas Hidayat *et. al.,* 2020
India	98.65	0.39	-0.33	Length frequency	Present study

Note: L∞ - asymptotic length; K - growth constant; t_0 - age at zero length.

In the case of Pauly's empirical formula, the average annual surface temperature was taken as 27°C following Rao (1985); Reuben *et al.,* 1993. The 'M' value obtained in Pauly's formula is less than 1 for *Thunnus tonggol*. The L∞ (99.7 cm) was recorded from tropical and temperate waters of the central Indo-Pacific by Griffiths *et al.,* 2010. Analysis of relations between weight and dimensional parameters calculated from regression and correlation analysis of the growth was found to be isometric. The values obtained for linear regression and correlation coefficient in the present study are 2.65 (b) and 0.95 (r^2). Recent studies by Musel *et al.,* (2023) from Malaysian waters derived the results of 'b' value as 2.59 and r2 value as 0.94 and Darvishi M. *et al.,* (2018) obtained the values of 2.87 ('b') and 0.97 (r^2) from Iranian waters which are in agreement with the values obtained in the present study. This indicated a high degree of correlation and a better fit of the length-weight relationship. The observations made in this study support the works of Kaymaram, *et al.,* 2013, from Iran and Griffiths *et al.,* (2010) from Australian waters. The length-weight relationship equation and the derived value of W= 5.383x10-2FL2.65080 indicate isometric

growth with a high correlation coefficient ($r^2 = 0.9668$). The growth parameters resulted in a maximum length ($L\infty$) of 98.65 cm and a growth coefficient (K) of 0.39.

The Phi prime (ϕ') value of 3.72 suggests that the growth pattern is within the expected range for tunas Koya *et al.*, (2018) indicated a similar growth pattern as obtained in the present study.

Food and Feeding:

The food items preferred by *Thunnus tonggol* recorded in the present study are identified as fin-fishes, crustaceans and cephalopods. The prey organisms are comprised of small pelagic fishes particularly carangids, myctophids, anchovies, clupeids, crustaceans (mostly of *Acetes indicus*) and Cephalopods (only squids) reported in the study. A total of 652 samples were examined out of which 427 numbers are found to be in empty stomachs forming 65.49% and only 225 no. of samples (34.51%) had food remaining in the stomachs.

The food items in the stomachs of different size groups (Fork length) of *Thunnus tonggol*, examined indicated that the stomachs of *Thunnus tonggol* above 50 cm had negligible quantities of food items and below 50 cm it is observed that the food items are found in large quantities. The quarter-wise percentage of feeding intensity, as well as quarter-wise feeding condition in *Thunnus tonggol*, observed that more than 30% semi-digested matter followed by finfish averaging 25%, crustaceans 10% and Cephalopods at 5%. Quarter-wise variations in the composition of the diet are expressed as a percentage of total food items by weight for *Thunnus tonggol*. Based on the percentage of total food items the maximum food consumption for *Thunnus tonggol* was 59.19% observed in July-September and the minimum (2.39%) was in April – June.

The present study indicated that finfish, crustaceans, and cephalopods are primary dietary components. The study observed seasonal variations in feeding intensity, with a peak in July–September (59.19%), corresponding with reproductive cycles. Koya *et al.* (2018) identified that *T. tonggol* is a non-selective feeder, consuming over 22 taxa including fishes, cephalopods, and crustaceans and the feeding intensity varied at different reproductive stages. Koya *et al.*,2018 study result supports the present study Hidayat *et al*. (2020) also observed the dietary habits of *T. tonggol* in the Java Sea, and indicated a diverse diet comprising various fish species, cephalopods, and crustaceans. The present study strongly supports and is in agreement with the study of Hidayat *et al.*, 2020.

Maturity and spawning:

The samples of ovaries in different stages of maturity were selected and about 200 -250 ova from each ovary were taken out for measuring the diameters. The oocytes of the immature (stage I) ovary may

be termed as the general egg stock which are present in the ovaries of all stages of maturity. In stage II (Immature) ova of *Thunnus tonggol* measured between 0.02 and 0.027, In stage III (maturing) the immature ova developed to the maturing stage and measured between 0.039 and 0.068 mm. In stage IV early mature ova shows an increase in diameter between 0.072 and 0.081mm.

In stage V (mature) the ova show a slight increase in size ranging between 0.078 and 0.091. The ova of stage VI are fully ripe and are the ova ready to be spawned in the ensuing spawning season. In Stage VII (Spent) the ovary is in the spent stage with a membranous sac with a loose ovigerous tissue and a few distinct ova.

Fish with ripe gonads (stage V&VI) were encountered during August–December in *T. tonggol*, spent fishes were reported during December. The proportion of maturing females (stage III) was high in January-March decreased to the lowest level in May-August and thereafter increased to the highest level in December. Mature females were found in January-April and again in August-September. Spent females were observed in April-June and September-October. There appear to be two distinct spawning seasons for longtail tuna. Major spawning from January- May with a probable peak in March and a minor spawning during Aug. - Sep.

The size at first maturity revealed that the species *T. tonggol* attained maturity at 48 cm. At this size range, the fishes were found to be either in stage V or ripe (stage VI) or spent (VII), the minimum size at maturity (50%) for females of *T. tonggol* reported at 24 cm F.L.

A total of 652 (*T. tonggol)* specimens were examined for sex ratio analysis. In the present study, the male to female ratio for *T. tonggol* is found to be 1:1.3. The sex ratio indicates that there is no significant departure from the normal expected value. The results indicated that the observed proportion of males in different months is not significant. Analysis of the sex ratio in different size groups also revealed that there was no significant departure from the normal expected value.

The spawning season of a fish can be determined by the relative condition or Gonado Somatic Index (GSI). The Ganado Somatic Index in females will give better results than in males. The GSI values recorded ranged from 0.042 to 0.573 in *T. tonggol*. Sampling could not be done due to a uniform ban on fishing during June-July and hence, spawning season and duration could not be drawn more precisely in this period. The highest value of GSI reported in this study indicates the occurrence of mature or ripe specimens.

Fecundity is more or less inversely related to the size of eggs and to the care given to eggs and larvae. The fecundity depends on various environmental factors. The production of eggs varies not only among different species but also within the same species, depending on the length and weight of the gonads. Mature ovaries of *Thunnus tonggol* were selected for this study and the total number of ova in each

individual were analyzed. In the present study, 32 specimens of *Thunnus tonggol* (size range 45 to 72cm) were considered. The fecundity of *Thunnus tonggol* varies from 1,43,230 to 22,30,000.

Hidayat *et al.* (2020) reported that the species attains maturity at 60.7 cm fork length and spawns during the summer months starting from May in Java Sea, Indonesia for the species *Thunnus tonggol*. In the present case, the species attains maturity at 48.0 cm. The difference in size at maturity may be due to differential geographical environmental factors. The present study reports two distinct spawning periods, a major one from January to May, peak in March, and a minor one from August to September.

The minimum size at first maturity for females is reported as 24.0 cm FL, with full maturity at 48.0 cm FL. The Gonado Somatic Index (GSI) ranged from 0.042 to 0.573 and supports the works of Koya *et al.* (2018) from Indian waters and Hidayat *et al.* (2020) from Java Sea.

Proximate composition:

The percentage of proximate composition in the muscle tissue of *Thunnus tonggol* was analyzed and indicated that Moisture (71.0%), Protein (23.2%), Lipid (4.2%), Glycogen (0.4%) and Ash (1.4%). There exist large variations in the proximate composition of many species of fishes and also in the same species. This may be due to changes in season and habitat. Present study results support the works of Karunarathna & Attygalle, 2009 on the proximate composition of various tuna species, including *T. tonggol*, notes variations in nutritional content due to factors like diet and environmental conditions.

Conclusion:

This study provides a comprehensive assessment of *Thunnus tonggol* (Longtail Tuna) occurring in the North-Western Indian EEZ focusing on population parameters, and biological aspects and will be crucial for sustainable fisheries management. Findings revealed that the growth is isometric and has significant reproductive potential with two distinct spawning peaks. The species exhibits a non-selective carnivorous diet. Proximate composition indicated the species has desirable protein, low-fat and awareness could be provided on the nutritional value of the species. With an estimated size at first maturity of 48.0 cm FL and fecundity reaching over two million eggs, *T. tonggol* shows strong reproductive capacity. These insights offer a valuable baseline for developing region-specific conservation measures, including minimum legal size limits and seasonal closures, in order to ensure the sustainable exploitation of these important neritic tuna resources.

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