Review of historical and new data on Growth parameters and age of Yellowfin tuna, Thunnus albacores (Perciformes: Scombridae)

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Abstract:

This paper presents review historical and new data on of the growth performance and age of yellowfin tuna.

In this study the information and data of yellowfin tuna was collected from Federal Ministry of Animal Resources Red Sea fisheries Research Center and Fisheries data Red Sea Fisheries Research Station, 2017-Sudan) and literature cited.

Result shows that the yellowfin tuna, Thunnus albacares, is an important species in tuna isheries worldwide is a commercially important species of tuna inhabiting tropical and subtropical seas . In Sudan Red Sea there are 7 Tuna fish species. Knowledge of life history parameters was essential for understanding the population dynamics of yellowfin tuna (Schaefer, 1996). Several approaches were often used to determine the age and growth of the species, growth parameters, growth pattern and age. Determination of age by the analysis of marks on scales the fork length (cm) and wet weight (kg) of yellowfin the length-weight relationship was calculated as in Le Cren (1951). Estimated size of yellowfin at first maturity, calculation of the instantaneous annual mortality rate (Z), natural mortality calculations equation and mortality and exploitation rate.

Keywords: *growth and age parameters; yellowfin tuna; length weight relationship, fork length.*

Introduction:

The yellowfin tuna, Thunnus albacares, is an important species in tuna fisheries worldwide. In 1998, the global catch of yellowfin was over 1.1 million metric tons (FAO, 2000).

Although many aspects of the biology and population structure of yellowfin in wild populations have been studied (summarized in Suzuki, 1994; Wild, 1994), few attempts have been made to culture yellowfin for experimental or aquaculture purposes.

From 1970 to 1980 in Japan, yellowfin were reared in small scale studies, with some limited success at artificial spawning and rearing of larvae and early juveniles (Harada *et al*., 1971; Mori *et al*., 1971; Harada *et al.*, 1980).

The yellowfin tuna Thunnus albacares (Bonnaterre, 1788) is a commercially important species of tuna inhabiting tropical and subtropical seas worldwide, except the Mediterranean Sea (Margulies *et al*. 2001).Little is known about key biological parameters of the yellowfin tuna, such as age and growth.

Within the Red Sea Biological parameters, including age, growth, mortality and age (or size) at maturity are vital for more reliable stock assessments and management plans, and to ensure a sustainable development of the fisheries (Chen & Paloheimo 1994).

The Red Sea has a number of unique marine habitats, including sea grass beds, saltpans, mangroves, coral reefs and salt marshes. The Gulf of Aden is a region of oceanic upwelling, resulting in high productivity of fish resources, particularly in the eastern part of the Gulf of Aden. The Socotra Archipelago constitutes a separate ecosystem; the importance of its unique environment and endemic biodiversity is on a par with the Galapagos Islands.

The fisheries of the Red Sea and Gulf of Aden are of considerable socio-economic importance to the member states of the Regional Organization for the Conservation of the Environment.

The Red Sea and Gulf of Aden (PERSGA), in terms of national food security and income generation for rural communities.

Fisheries resources are exploited by artisanal subsistence fishermen, local commercial fisheries and foreign industrial fisheries targeting invertebrates, demersal finfish and pelagic finfish. Many species cross national boundaries and are essentially shared stocks.

WHAT IS TUNA?

Tuna is not a single species of fish, but rather several species. Scientists often use the term “tuna and tuna-like fish” to refer to a total of 61 species, 14 of which are considered “true tuna.” Four species are of major commercial importance in the Indian Ocean: skipjack, yellowfn, big eye, and albacore. The most important tuna-like species in the Indian Ocean is swordfish.

These five species3 are quite distinct with respect to many properties, such as how they are captured, the amount presently captured, the size of the populations and the end use of the product.(Tuna for tomorrow Robert Gillett, Indian Ocean Commission) www.coi-ioc.org.

In Sudan Red Sea there are 7 Tuna fish species

Rastrelliger kanagurta known as (small eye tuna), Scomberomous indicus kanagurta known as big eye tuna, Scomberomorus commerson known as Spanish mackerel, Scomberomorus guttatus known as (indo-pacific Spanish), Auxis thazard known as (Frigate mackerel), Katsawonus pelamis(Skipjack Tuna), Thunnus albacores known as (yellow fin tuna). (Report, UNIDO, 2017).

These tuna are fast growing, mature at about 2 years of age and spawn prolifcally. Yellowfn can grow to over 100 kg at 6 years or older. The majority of the catch is taken from the equatorial region where they are harvested with a range of gear types, predominantly purse seine and long line.

For stock assessment purposes, yellowfn tuna are believed to constitute a single stock in the Indian Ocean.

Yellowfin tuna, Thunnus albacares, (Bonnaterre, 1788) is a pelagic migratory species found throughout the tropical and subtropical waters of the world, and has been widely studied due to its high economical value. Most commercial landings of yellowfin tuna were caught by the purse seine and long line fleets.

Knowledge of life history parameters was essential for understanding the population dynamics of yellowfin tuna (Schaefer, 1996). Several approaches were often used to determine the age and growth of the species, such as length-frequency analyses, tagging and recapture experiments and observations of the mark on the hard parts, i.e., scales, otoliths, spines and vertebraes (Stequert *et* *al*. 1996).

The objectives of the present study are:

To provide of some information on the growth, age and mortality of yellowfin tuna collected in the Red Sea area and Pacefic region, by using fork length data and the Elefan I technique (Pauly 1987).

This may be useful in managing the rapidly developing fishery of yellowfin tuna in the world.

The objective of this work is to present an overview of the current status of yellowfin tuna fisheries in the Region and identify particular problems in regard to the sustainability of fisheries and their effect on the environment.

Materials and methods

The fork length (cm) and wet weight (kg) of yellowfin tuna were collected on a weekly basis from the landings made by the commercial hook and line and long-line operators of during 2003-2009.

The length-weight relationship was calculated as in Le Cren (1951).

Growth 2 parameters viz., asymptotic length ($L\propto$) and growth coefficient (K) were estimated using the ELEFAN I module of FiSAT software and the Powell-Wetherall plot (Gayanilo *et al*., 1996).

The length based growth performance index

$Ø = \text{Log } K + 2 * \text{Log } L\propto$

Was calculated as in Pauly and Munro (1984) and the age at zero length (t0) from Pauly's

(1979) empirical equation. Longevity was estimated from t max = 3/K+t0 (Pauly, 983a). Natural mortality (M) was calculated by Pauly's empirical formula (Pauly, 1980) and total Mortality (Z) from length converted catch curve (Pauly, 1983 b). Exploitation ratio was estimated from the equation,

E= F/Z and exploitation rate from U=F/Z (1-e-z); where F is the fishing mortality rate

Maturity (age and size)

The estimated size of yellowfin at first maturity varies considerably throughout the Pacific Ocean. Biffiag (1956) collected a maturing female 57 cm fork length from the region near the Philippine Islands, Yuen and June (1957) estimated the size of first spawing for fish in the central Pacific to be approximately 70 cm, although the greater share of the females did not reach

maturity until about 120 cm.

Orange (1961) reported a wide range in size of first maturity for areas within the eastern Pacific Ocean, In the north, around the Revillagigedo Islands, few yellowfin mature below 80 cm total length, and the average size of first maturity is estimated at 100 cm. However, in areas off Central America, a substantial share of maturing females is found in the size-group from 50 to 60 cm total length.

Data collection

A number of publications produced by organizations and individuals were collecting information as secondary data sources.

Survey Information:

This study was carried out using the followings:

Age and growth information

Age and growth information of yellowfin tuna can be obtained from a variety of techniques such as (a) length modes small yellowfn are caught on the surface by purse seine, gillnet, pole/line gear and trolling while larger/older fish are caught in deeper water using long line gear.

Age determination

Direct determination of age by the analysis of marks on scales, vertebrae or other hard parts, has not proven reliable for the tropical tunas.

For this reason estimates of yellowfin tuna growth have been derived from analysis of length-frequency distributions of fish taken in the commercial catches, and from changes in length exhibited by recaptured tagged fish. Moore (1951) examined the length-frequency data for fish taken by the commercial longline fishery in the central Pacific Iversen (1956) examined data from fish from the central and western Pacific; Yabuta and Yukinawa (1957b) examined data from fish from Japanese waters; and Hennemuth (196la and l961b) studied data for fish from waters of the eastern Pacific.

Blunt and Messersmith (1960) and Schaefer,Chatwin and Broadhead (1961) reported on the growth of recovered tagged yellowfin tuna from the eastern Pacific region. All authors were in general agreement that the yellowfin tuna grow at a rapid rate and enter the commercial fishery (for surface schools) at about the end of their first year of life, Hennemuth (196la) concluded that the rates of growth of fish from the western, central and eastern Pacific regions were quite imilar.

Hennemuth (196 la) notes that the rates of growth for yellowfin tuna from the eastern, central and western Pacific are similar although the assignment of actual ages to the modal groups which can be traced is not entirely firm.

However, the combination of the age estimates with estimates of size at first maturity, suggests that yellowfin tuna, for the most part, spawn initially during their second year of life.

Length-frequency data of the yellowfin tuna (Thunnus albacares) caught by the Taiwanese offshore long line vessels was collected monthly at Tungkang fish market between September 2001 and October 2002. These samples were used to estimate the von Bertalanffy growth parameters and the mean length at age for yellowfin tuna by the length-based MULTIFAN method. Twenty-four cases were considered and the best match was found in the case when April was set as month 1, the sample number was merged to 12 by month and 3 cm was selected for length interval. In this case, the von Bertalanffy growth parameters were estimated as growth coefficient K = 0.392 yr-1

, asymptotic fork length FL8 = 175.0 cm, and theoretical age at zero length t_0 = 0.00306 yr. Six age classes were identified and mean length at age was L1 = 56.16 cm, L2 = 95.00 cm, L3 = 120.95 cm, L4 = 138.48 cm, L5 = 150.32cm, and L6 = 158.32 cm. The estimated longevity (tmax) was 7.65 years.

Mortality rates

For the calculation of the instantaneous annual mortality rate (Z) the length-converted catch curve (Pauly 1983, Munro 1984) was applied to the pooled length frequency data using the estimated growth parameter.

The calculation was done with the FiSAT program (Gayanilo & Pauly 1997).

The natural mortality was calculated by Pauly's empirical equation:

logM = 0.1228 – 0.192 log L' + 0.7485 log k +0.2391 log T, where: T = the mean annual temperature (in °C), which is assumed to reflect the locally sea surface temperature in the survey area (Pauly 1980)

(in the present study, T = 26.4°C);
M = natural mortality.
In order to obtain the L'
value, the present study used the relationship between fork length and total length (TL) on yellowfin tuna from the Fish base database (TL = 1.108L, www.fishbase.org) and combined the L value estimated from the equation.
For the calculation of the fishery mortality (F), the M value was subtracted from the Z value in order to get the fishing mortality (F = Z – M) (Sainsbury 1982, Appeldoom 1984, 1988).
With the estimated values of F and Z the rate of exploitation (U) was calculated according to Landau (1979) and Gulland (1985).

Analysis based on length-converted catch curve showed that total mortality (Z) and natural mortality (M) reached 2.11 and 1.22, respectively, with an average temperature of 31oC. The fishing mortality (F) was 0.89, while the exploitation ratio (E) was 0.42. The results are depicted

Mortality and exploitation rate. Natural mortality (M) was calculated at 0.66 year-1 and fishing mortality (F) at 0.61 year-1

Taking Z= 1.27 into account, an exploitation level (E) of 0.48 year-1 was obtained for T. albacares in the Palabuhanratu waters, which seem to be lower than the expected optimum level of exploitation (E = 0.50). The reliability of the estimated M was ascertained using the M/K ratio because this ratio reported to be within the range of 1.12-2.50 for most species (Beverton & Holt 1957, in Zhu *et al* 2011). The value of M/K ratio in this study was 1.22.

Comparison of mortality and exploitation rates from several studies in other sites with varying values is indicated in Table 2. The estimation of natural mortality (M) ranged from 0.48 to 0.68 year-1, fishing mortality (F) ranged from 0.23 to 1.79 year-1, total mortality (Z) ranged from 0.71 to 2.40 year-1 and an exploitation level (E) ranged from 0.32 to 0.77 year-1.

Growth of yellowfin tuna:

In this study, we use both otolith counts of daily micro-increments and data from a large tagging experiment to investigate the growth of yellowfin tuna in the western and central Pacific Ocean Age and growth of yellowfin in the WCPO 3 Results confirmed the occurrence of a period of slow growth in the juvenile phase of yellowfin in the WCPO. A growth model is proposed by using the classical Von Bertalanffy model with the growth parameter *K* varying according to a normal distribution. The biological significance of this model is discussed and results are compared to previous studies devoted to yellowfin tuna growth.

Biological parameters such as growth and age (or size) at maturity are vital for accurate stock assessments and management plans to ensure that fisheries develop sustainably. Despite this,very few validated age studies have been conducted for large tropical pelagic species within the Australian region. (Lowe, 1839)

The present analysis was based on the analysis of 4698 recoveries, and its results are showing that the growth of yellowfin tuna as estimated from recoveries, tend to show a quite clear 2 stanza pattern.

1. between 40 cm and 60 cm: during their early stages in the PS fishery, in this range of sizes (about 1 to 4 kg), yellowfin tunas tend to show a very slow growth at an average monthly rate of 1.5 cm /month, when the previously used Von Bertalanffy model proposed by Stequert et al 1996 estimated an average growth rate of 3.8 cm / month in this range of small sizes. Although uncertainty is rather big due to the small number of very small yellowfin tagged, these smallest sizes tagged, for instance in the range between 38 and 44 cm, tend to show higher growth rates. Growth rates are minimum around 48cm, followed by a flat and low growth rate until about 58 cm.

2. between 60 to 75 cm (about 8 kg) of fork length, there is a steady increase of the apparent growth rate, from 1.4 cm/month to nearly 4 cm/month (average 2.5 cm/month),when the previously used Von Bertalanffy model proposed by Stequert 2004 estimated a declining growth rate at an average of 3.2 cm / month in this range of sizes.

3. fishes larger than 75 cm are showing a slowly declining growth rates, then a trend similar to the Von Bertalanffy model, but at relatively high absolute growth rates of 3 cm/month, that are constantly higher than the growth rates of 2.2 cm /month estimated by the Stequert et al 1996 Von Bertalanffy model in this size range.

Furthermore, these growth rates could be increased of about 10 %, when assuming a 2 % shrinkage factor after the tuna death and their freezing.

As a conclusion, based on these results, the composite growth model is built, first using the recovery data in a range of size between 38 and 90 cm, and later using the Stequert *et al* 1996 Von Bertalanffy growth rates at size after 90 cm. Such rebuilt growth pattern has been used to make the figure 7a and its plotrec diagram (Fonteneau and Nordstrom 2000).

Showing the recoveries and this growth curve. Figure 7b shows the same recoveries adjusted to the Stequert *et al* 1996 growth model (and clearly, as expected, this fit to the Von Bertalanffy model is not good).

The significance and coverage of the age/sizes recovered in the present tagging results are widely different between the three species tagged, 10 comparing the sizes tagged and fished in the Indian Ocean:

Young yellowfin recruits in the fisheries at sizes under 40 or 45 cm have been very seldom tagged (only 3.7% of the recovered yellowfin), when the dominant mode in the yellowfin fishery, between 45 and 70 cm, has been tagged in great numbers. Large yellowfin have been very seldom tagged (only 16 yellowfin tagged over 1 meter have been recovered, i.e. 0.3 % of the yellowfin tagged), but as PS fisheries are catching a large proportion of these large yellowfin, and as the reporting rate of tagged fishes has been very good on this fleet, a large number tagged yellowfin will soon by recovered by this fleet. A total of 1525 recoveries of large yellowfin caught over 90 cm (33% of the recovered yellowfin) have been already reported (i.e. potential spawners, in a size

range between 90 and 156 cm). It can then be concluded that yellowfin growth will soon be well estimated from these recoveries and during the entire life of this species,based on the large number of recoveries of large yellowfin expected during the next 3 to 5 years from purse seiners.

At this stage, the more realistic conclusion is probably that tropical tunas do not follow a Von Bertalanffy growth curve, but most often (yellowfin and bigeye) a much more complex growth curve in relation with the changes in the biology and in the ecology/behaviour of these fishes:

- Post larvae to 40 cm (1 kg), yellowfin and bigeye: an initial fast growth necessarily takes place during the cryptic pre-recruitment and pre-tagging period, between the end of larval stages (first month in the life of a tuna) and the size at recruitment in the fisheries: these very young fishes are

probably showing an increase of size between larvae and juvenile of about 30 cm during about 6 month (Eastern Pacific, Wild 1992) or during only 4 month in the Atlantic, based on the seasonality of the spawning season (Capisano and Fonteneau 1990), i.e. with a fast average growth rate of these early pre-recruited fishes of about 5 cm or 7.5 cm /month.

- At larger sizes in the 40 to 70 cm range: juvenile growth is slowing down to an average monthly rate of only 1.9 cm /month in the 40 to 70 cm (1.47 cm/month in the Atlantic, Capisano *et al* Fonteneau 1990), when a much faster growth is predicted by the Von Bertalanffy model during this early period. During this recruitment period, juvenile tunas tend to be concentrated in their equatorial nurseries, in the shallow and warm equatorial waters, between 10°N and 10°S.

Frequency distribution equation:

Frequency of fish length determined interval, mean, and frequency in each group. Measurement of fish length was based on frequency distribution equation (Walpole).

Where:

K = number of classes;

N = number of data;

i = class interval;

R = maximum value and minimum value.

Fish growth parameters (K and L) were estimated using ELEFAN I sub-program of FiSAT II software (Gayanilo *et al*)

The age data were assessed using von Bertalanffy Growth Function (VBGF) and (Bevertonand Holt formula:

Lt = fish length at age t;

$L\infty$ = asymptotic length;

K = growth coefficient;

t_0 = theoretical age when the sample was at zero length.

The theoretical age of fish was estimated when the sample was at zero length using following formula (Pauly).

Natural mortality (M) was determined using empirical equations (Pauly) as follow:

Where:

M = natural mortality;

L = asymptotic length;

K = growth coefficient;

T = average temperature of 31°C (data collected).

Total mortality (Z) was obtained using length-converted catch curve (Pauly) [19]. Exploitation (E) was obtained from E= F/Z,

while fishing mortality (F) was obtained from following formula: F= Z-M (Sainsbury and Appeldoom; Kantun and Amir)

Where:

M = natural mortality;

E = exploitation rate;

Z = total mortality;

F = fishing mortality.

Excessive stock was not based on the assumption of optimal value (Eopt) > 0, 50. This assumption showed that the sustainable capture could be reached on F > M (Gulland,).

Growth Pattern

The length frequency of yellowfin tuna was analyzed using von Bertanlanffy. The results showed that maximum length ($L\infty$) and K value was 117.08 cm and 0.93 per year, respectively. Theoretical age was 0.10 years, while the growth prospecting index (Ø) was 4, 10. Growth curve of yellowfin tuna in waters of Simeulue Islands (Lasia and Babi islands).

Mortality:

Analysis based on length-converted catch curve showed that total mortality (Z) and natural mortality (M) reached 2.11 and 1.22, respectively, with an average temperature of 31ºC. The fishing mortality (F) was 0.89, while the exploitation ratio (E) was 0.42. The results are depicted

Mortality and exploitation rate. Natural mortality (M) was calculated at 0.66 year-1 and fishing mortality (F) at 0.61 year-1.

Taking Z= 1.27 into account, an exploitation level (E) of 0.48 year-1 was obtained for T. albacares in the Palabuhanratu waters, which seem to be lower than the expected optimum level of exploitation (E = 0.50). The reliability of the estimated M was ascertained using the M/K ratio because this ratio reported to be within the range of 1.12-2.50 for most species (Beverton & Holt 1957, in Zhu *et al* 2011). The value of M/K ratio in this study was 1.22.

Comparison of mortality and exploitation rates from several studies in other sites with varying values is indicated in Table 2. The estimation of natural mortality (M) ranged from 0.48 to 0.68 year-1, fishing mortality (F) ranged from 0.23 to 1.79 year-1, total mortality (Z) ranged from 0.71 to 2.40 year-1 and an exploitation level (E) ranged from 0.32 to 0.77 year-1.

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Table 1: Differences in age of yellowfin tuna captured from various locations

References	**Method used**	**Locations**	**Fork Length (FL)**					
Age								
1	**2**	**3**	**4**	**5**				
Rohit *et al*. [22]	Length	Hindia Ocean	56	92,8	120	140,0	155	
Somvanshi *et al*. [25]	Length	Exclusive Economic Zone (EEZ)	35	63,9	87,5	107	123	
John [11]	Length	Andaman and Nicobar Islands	58	88,7	111	128	139	
John and Reddy [12]	Length	Hindia Ocean	77.0	101.7	120.1	134.0	144.3	
Current work	Length	Semeulue Waters	75,0	100.5	110.5	114,5	116.5	

Table 2: Estimated growth pattern of yellowfin tuna in some locations

L∞(cm)	**K**	**To**	**Locations**	**Source**
175.00	0,29	-	East coast of India Ocean	John and Reddy [12]
171,50	0,32	-0,31	Andaman and Nicobar	John [11]
193,00	0,20	-	EEZ India	Somvanshi *et al*. [25]
197,42	0,30	-0,12	East coast of India Ocean	Rohit *et al*. [22]
117.08	0.93	0.10	Semeulue waters	Current work

Table 3: Estimated mortality of yellowfin tuna

Z	M	F	E	Location	References
2.04	0.48	1.56	0.76	Oman sea	Kaymaram*et al* [15]
0.71	0.48	0.23	0.32	East Cost of India	Rohit*et al* [22]
1.56	0.65	0.91	0.46	Eastern & Central Pacific Ocean	Zhu *et al* [28]
1.27	0.66	0.61	0.48	Palabuhanratu	Nurdin *et al* [17]