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Dynamics Population of Yellow fin Tuna *Thunnusalbacares* in Bone Bay, Indonesia

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Abstract

The finding the study to measure some key characteristics of the population dynamics of yellowfin tuna. A total of 12.936samples were collected using handline fishing and measured forfor k length with a precision of 1 cm. Growth parameters of von Bertalanffy were identified using ELEFAN method and FiSAT II software, while natural mortality was obtained according to Pauly's empirical formula. The range of fishing mortality also accounted for the parameter of the population dynamics. Yield per Recruit (Y/R) was calculated using the standard formulation of Beverton and Hold. The estimated growth parameter corresponded to length infinity = 220 cm and growth rate = 0.37 per year. The resulting index of growth performance was 4.261. Total mortality was found at 2.25 per year^{-1}, natural mortality at 1.71 per year^{-1}, fishing mortality at 0.54 per year^{-1}and exploitation rate at 0.76 per year^{-1}. These findings, which highlight the importance of research in connection with population dynamic parameters, can set out the guideline for yellow fin tuna management in Bone Bay.

Key Words: Thunnusalbacares, growth paramater, mortality, Bone Bay.

1. Introduction

Yellowfin Tuna or YFT (*Thunnusalbacares*) is of great importance to both local and global economy among large pelagic species. The fish is mainly distributed through out subtropical and tropical regions of the Atlantic Ocean, Indian Ocean and Pacific Ocean, migrating over large distances across vast continents so that fishermen can exploits tocks world wide. To maintain its livelihood and sustainability, provisions on yellow-tailed tuna are managed by several Regional Fisheries Management Organizations (RFMOs) i.e., the Western and Central Pacific Fisheries Commission (WCPFC) in the Pacific Ocean and Indian Ocean Tuna Commission (IOTC) in the Indian Ocean. The Ministry of Maritime Affairs and Fisheries of the Republic of Indonesia, MMF-RI reports that YFT accounts for Indonesia's most leading fishery export commodity only second to shrimp. The Ministry of Maritime Affairs and Fisheries, MMAF, reports that some YFT stocks in WPPNRI 713 (Regional FisheriesManagementZonesofthe Republic of Indonesia) are already over exploited with a risk of stock collapse. IOTC[1] reports that the Indian Ocean saw a rapid increase in YFT production from 127,959 tons in 1980 to 385,291 tons in

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2000 and 412,679 tons in 2016, strongly indicative of over fishing that calls For adequate governmental capacity for rational fishing practice and management improvement. Provisions on management policies and rational use must correspond to scientific evidence on which research outcomes are based using correct methods. Data and information about the biology and population dynamics of fishre sources are methodological aspects that essentially contribute to the provisions of rational fish management and utilization policies [2]. Studies of stock dynamics are a key pre requisite for effective management plan of fish resources. Studies on Yellow fin Tuna in Indonesia have connected with the measurement of population dynamics concerning several fundamental aspects such as the structures and parameters of population dynamics in the waters of Banda Sea [3]; size distribution of catches in Banda Sea waters[4]; size structure and number of catches in deep and shallow FADs in Makassar Strait waters [5] the relationship between oceanographic characteristics and catches in Banda Sea[6]; biological aspects and catch composition in the waters of Bone Bay [7]; and population dynamics and stock conditions in Banda Sea[8]. Based on the afore mentioned, a considerable body of studies on the dynamics of yellow fin tuna populations have not been extensively conducted in Indonesia; many areas have not been adequately investigated particularly in Bone Bay. In the present study, the conception and analysis of population dynamics are scientifically defined with respect to growth, mortality rate, recruitment and exploitation of yellow fin tuna in Bone Bay waters. The applicability and utility of scientific outcomes of the study can navigate policy management and rational use of yellow fin tuna in the area of interest.

2. Material and Method

2.1. Period and Location of The Research.

The dataset was available from the investigations carried out from July 2018 to June 2019 in the waters of Bone Bay, South Sulawesi, Indonesia (Figure 1). Sampling was conducted at two base locations and landing are as for yellow fin tuna fishermen who practiced hand line fishing. Station I was located at CimpuVillage, Luwu Regency, South Sulawesi, and Station II at LonraeVillage, Bone Regency, South Sulawesi, Indonesia.

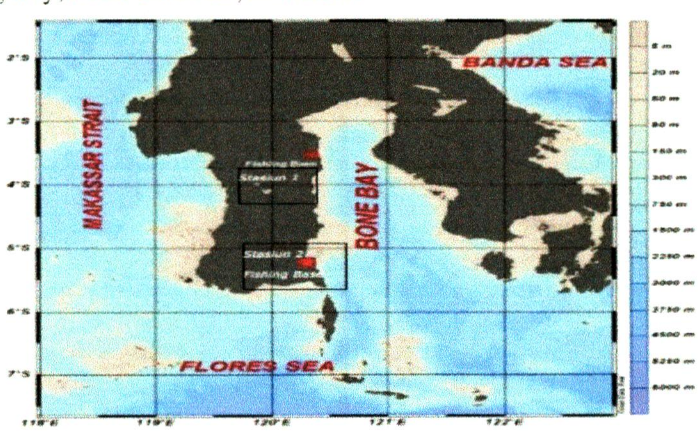

Figure1.Bone Bay as Research Area

Plastic tags were used for marking in the evaluation of fish samples. A measuring board for recording for k length was specifically designed for large pelagic fish. Digital thermometer was used for water temperature measurement. Ice was utilized in fish preservation. Software and digital applications such as FiSATand Microsoft Excel were used for information and data processing. Fish samples were caught in the waters of Bone Bay using hand line fishing at a depthof± 50 meters.

2.2. Data Analysis.

The estimation of population dynamic parameters was subject to for k length data of yellow fin tuna. For k length was measured from the outer edge of the snout to the tip of the tail. Sample measurements were carriedout every 7 days simultaneously at both stations. Samples were measured in centimeter units with a precision of 1 cm. ELEFAN system and FiSAT II software fit the calculation of growth parameters The exponential growth equation of von Bertalanffy was taken to observe the growth parameters of yellow fin tuna[9].

$Lt = L\infty\left[1 - e^{-K(t-t0)}\right]$(1)

The value of t_o was on the basis of the empirical equation of Pauly[10]:

$\log(-t_o) = -0.39222 - 0{,}2752 (\log L_\infty) - 1{,}038 (\log K)$(2)

The growth index value was taken to observe the growth of yellow fin tunas in the waters of Bone Bay in comparison with those in other studies. Such index is also known as phi-prime[9]:

$Ø = \log K + 2 \log (L_\infty)$(3)

The total mortality rate was obtained from the length-converted catch curve method using FiSAT II[11]. Natural mortality rate was estimated using the empirical formula of Pauly[9]:

$M = 0.8 \times Exp(-0.152 - 0.279 \log L_\infty + 0.6543 \log K + 0.4634 \log T^0C)$ (4)

Mortality rate in terms of catch (F) was calculated into the following equation:

$Z = M + F$(5)

and

$F = Z - M$ (6)

The estimate of exploitation rate was modeled in Beverton-Holt'sequation[2] in FiSAT II:

$\frac{Y}{R} = E * U^m\left[1 - \frac{3U}{1+m} + \frac{3U^2}{1+2m} - \frac{U^3}{1+3m}\right]$(7)

Where:

$U = 1 - \frac{Lc}{L\infty};$ (8)

$m = \frac{1-E}{M/K}$ (9)

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Where:

Lt	= Length of fish at age t (cm);
L ∞	=Length at infinity (cm);
Lc	= Smallest Length in catch≥ 50% (cm);
t	= Age of fish (year);
t_o	= Theoretical age the fish would have at length zero(year);
K	= Coefficient of growth rate(per year);
Z	= Total mortality rate;
M	= Natural mortality rate;
F	= Fishing mortality rate;
E	= Exploitation rate;
T	= Average water temperature (°C)

3. Result And Discussion

3.1. Result

3.1.1. StructureSize, Group and Age.

The number of fish samples measured during the study was 12.900 specimens of yellow fin tuna within lengths between 20 and 192 cm (± SE 0.778) with an average length of 84.2 cm (±SE 0.778). The majority of the samples (>500 specimens) attained for k lengths (FL) of 32.5 – 52.5 cm and 67.5 -112.5 cm (Figure 2).

The relative age of the fish samples was estimated between 0 and 6 years. The length distribution of the samples was assigned to 4 cohorts (Figure 3).

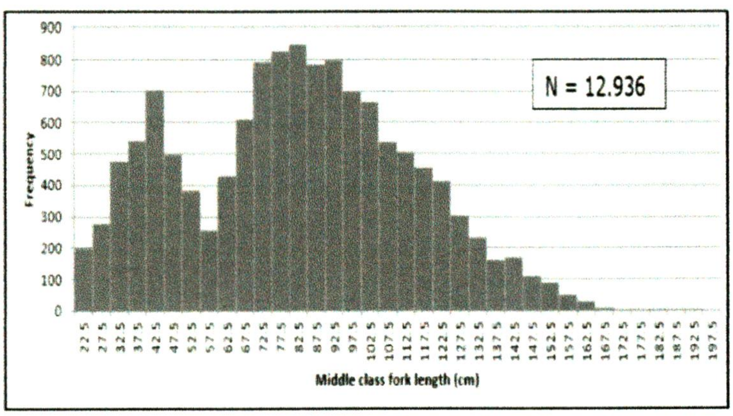

Figure2. SizeCompositionofYellowfin Tuna in theWatersof Bone Bay

The average length was 38.66 cm (SD±12.75) in cohort I; 83.26 cm (SD±14.97) in cohort II; 118.32 cm (SD±13.32) in cohort III;and 148.91 (SD±7.01) in cohort IV.

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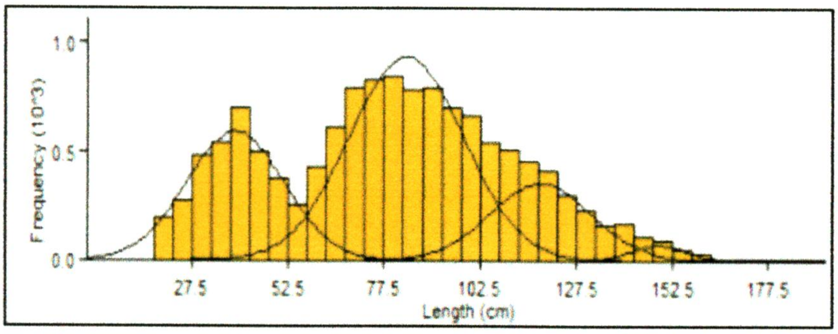

Figure3.The CompositionofSizeandNumberofYellowfin Tuna Cohorts in theWatersof Bone Bay

3.1.2.Population Growth.

The outputs of FL data analysis using ELEFAN-based system and FiSAT II are presented in growth curves as Figure 4 and Figure 5 show below. Von Bertalanffy's growth parameters for Yellow fin Tuna were estimated as $L\infty = 222{,}0$, $K = 0{,}37$ year^{-1}, $t_o = -0.5897$ yearand $\phi = 4{,}261$. These parameters were formulated in Von Bertalanffy's growth equation:

$$L_t = 222{,}0(1\text{-}exp^{-(0.37(t+0.5897)})$$

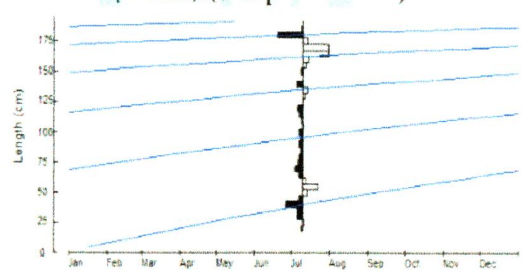

Figure4.Growth Rate ofYellowfin Tuna in von Bertalanffy'sEquation

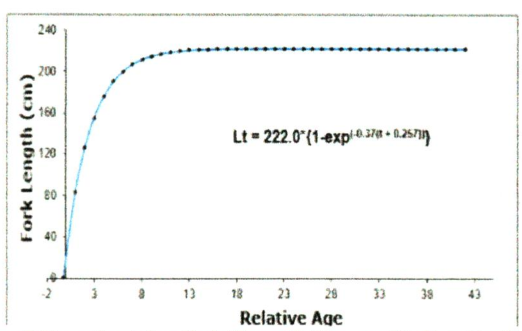

Figure5.Von Bertalanffy'sGrowthCurveofYellowfin Tuna in theWatersof Bone Bay

3.1.3. Mortality Rate.

The total mortality rate of the samples was 2,25 $year^{-1}$ (Figure 6); the fishing mortality rate (F) was 1,71 $year^{-1}$; and the natural mortality rate was 0,54 $year^{-1}$.

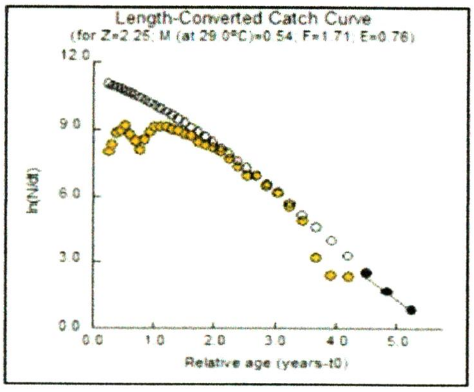

Figure6.Mortality Rate of Yellow fin Tuna in the Waters of Bone Bay

3.1.4. Exploitation and Recruitment Rate.

The estimation of exploitation rate (E) was 0,76 $year^{-1}$.Exploitation rate defines the proportion of population caught in the waters of Bone Bay. The calculation outputs corresponded to Lc/L∞ = 0,4 and M/K = 1,46, while the values for E_{max} and E_{opt} were 0,601 and 0,515, respectively.

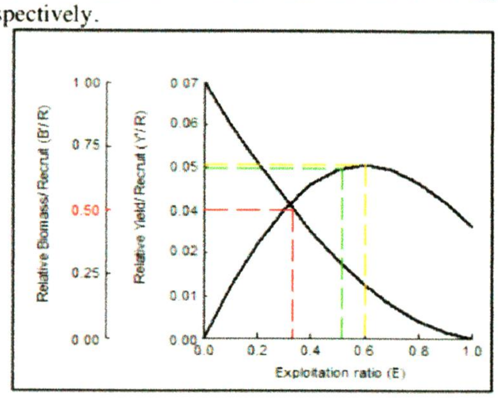

Figure7.Beverton& Holt's RelativeYield-per-Recruit Model (Y/R) forYellowfin Tuna in theWatersof Bone Bay

3.2. Discussion.

3.2.1. Size and age Composition

The size composition of Yellow fin tuna samples was grouped into three life stages, i.e., larvae (<20cm), juveniles (20 – 99cm) and adults (≥100 cm) [12]. Juvenile group was recorded to be the most abundant group in the catch in the waters of Bone Bay, i.e., 8.147 individuals (63,2%), followed by those in adult group, i.e., 4.753 individuals (36.9%). During the study periods, the highest number of samples were obtained in September 2018, i.e., 2.722 specimens.

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Table1ForkLengthsOfYellowfin Tuna In DifferentLocations

Location	*Rangesin FL (cm)*	*FLin Average (cm)*	*Study Period*	*Reference*
Indian Ocean (Bali &Lombok)	81-171	129,28	2009	[16]
Indian Ocean	43-178 (M) 30-170(F)	135,3 130,8	2005 –2013	[17]
Benoa, Bali Indonesia	75-179	133,71	2011	[18]
Banda Sea	25-178	94,0	2015–2016	[8]
Banda Sea	55-215	-	2011	[3]
Simeulue Island Waters, Aceh, Indonesia	45,5-111,5	-	2016	[14]
East Coast Of India	20-185	101,9	2003–2009	[19]
Bone Bay, Indonesia	40 - 160	Na	2011	[7]
Bone Bay	34 – 38	36,25	2016	[20]
Bone Bay, Indonesia	20 – 180	81,25	July 2018– June 2019	The Present Study

The smallest size of the samples was 20 cm, similar to the study conducted in the East Coast of India [13]. The finding of the present study also corresponded to that of the study in Banda Sea in terms of an average length[8], but was smaller than those in other prior studies (Table 1). It is interesting to note that the reappeared to be considerable difference in size among the handline-caught fish in the same waters between the present study (20 cm) and prior study (40 cm) [7]. Such difference in catch composition and of target species has often taken place and may be subject to several factors such as the depth of waters where catch operations carryout[14]; [5]. Handline gears used in the waters of Bone Bay for yellow fin tuna have a main rope of ± 50 meters in length, while yellow fin tuna can strive in the> 150M depth range[15].

3.2.2. Growth Rate

Yellow fin tuna has a maximum length that varies with location and time of study (Table 2). Prior studies in different locations indicate differences in the values of von Bertalanffy's growth parameters ($L\infty$, K and t_0). These differences are generally attributable to environmental conditions, food resources, periods of study, composition in fish samples, fishing methods, and fishing purposes[21].

L_∞ in several waters ranged between 159 cm and 223 cm within which the present findings were ideally obtained, thus making them in compliance with the range of reasonable values. L_∞ in the present finding is higher than those in other findings [13],[18][21];[22]; [23]; and[24], but is smaller than a few others[3]; and [8] (Table 2).

K valueis a curvature parameter that measures the extent to which the fish approach L_∞[9]. K value may be classified into slow growth (K<0,5), moderate growth (K = 0,5-0,75) and fast growth (K >0,75) [7] [25]. Based on the classification, the resulting K value in the present study fits into slow-growing population (0,37< 0,5), suggesting that the yellow fin tunas in the waters of Bone Bay required more adequate time to approach their a symptotic for k lengths.

This finding resonates with the prior study conducted in the East Coast of India [13], or more recently in Teluk Mexico [22], Banda Sea[8]. On the other hand, a prior study in Banda Sea presented a higher value than the present study [5]. Higher values, set at K>0,5, can also be identified in Bali and the surrounding waters[18], in the Eastern and Central Pacific Ocean[23], and in a few other regions (seeTable 2). The resulting Ø value in the present study indicates a reasonable performance index, in connection with the reviews of several studies (Ø > 4) [25]. Growth parameters may vary with genetic structures, environmental temperature, food resources [26], water areas, sampling methods, fishing gears, sampling periods [25], seasons, food, and developmental phases[3].

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Table 2 The Estimation Of Von Berlanffy's Growth Parameters For Yellow fin Tuna In Different Locations

Location	*Von Bertalanffly's Growth Parameters*				*N*	*AnalysisMethod*	*Reference*
	L∞	K year¹	t_o year¹	Ø			
East Coast of India	197.4	0.4	-0,.2	4.0	6.758	ELEFAN	[13]
Mexico Gulf	159.71	0.35	-0.296	-	1.106	AnnualIn cre-ments	[22]
Banda Sea	215	0.31	-0.31	-	4.829	ELEFAN	[8]
Bali Waters (Benoa Bali)	185.5	0.59	-0.22	-	3.092	ELEFAN	[18]
Eastern and Central Pacific Ocean	175.9	0.52	019	-	443	ELEFAN	[27]

Table 2 (continued)
The EstimationOf Von Berlanffy's GrowthParameters For Yellowfin Tuna In DifferentLocations

Location	*Von Bertalanffly's Growth Parameters*				*N*	*AnalysisMethod*	*Reference*
	L∞	K year¹	t_o year¹	Ø			
The Andaman AndNicobarWaters	173.3	0.39	-0.099	4.07	966	ELEFAN	[24]
Bone Bay, Indonesia	222,0	0,37	-0.5272	4.26	12.90	ELEFAN	The Present Study

L∞ =length infinity; K = growth rate coefficient; t_o= theorytical age at zero length; ø = growth performance index; N = number of fish sample

3.2.3. Mortality

Table 3 presents several findings that identify themortality rates of yellow fin tuna in several bodies of waters. The resulting values of M, F, and Z fit into a moderate category within a range of 1 – 2 based on the classification by Haruna et al.[8]and Mallawa et al.[28],which interprets F < 1 as low, F = 1.0-2.0 as high and F > 2.0 as extremely high. If yellow fin tuna is constantly predisposed to have a high incidence of exploitation in the waters of Bone Bay, the resource will suffer from various degrees of overfishing. This predisposition is evident in the exploitation rate at 0.76, which exceeds the maximum sustainable yield.

Table2Natural Mortality Rate, Fishing Mortality Rate, andExploitation Rate ofYellowfin Tuna in DifferentLocations

Fishing area	*M year⁻¹*	*F year⁻¹*	*Z year⁻¹*	*E*	*Reference*
Makassar Strait, Indonesia	0.52	1.69	2.21	0.68	[7]
Central Atlantic Ocean	0.39	0.54	0.82-1.02	0,.5	[29]
Andaman and Nocobar Waters	0.51	0.83	1.34	0.62	[24]
Eastern Coast India	0.48	0.23	0.71	0.32	[13]
Oman sea	0.48	1.56	2.04	0.79	[30]
Banda Sea	0.49	0.98	1.47	0.67	[8]
Banda Sea	0.68	1.79	2.4		[3]
West Java Indonesia	0.66	0.61	1.27	0.68	[21]
Bone Bay, Indonesia	0.54	1,71	2.25	0.76	The present study

4. Conclusion.

The great bulk of yellow fin tuna catches in the water of Bone Bay was found among juvenile group with a relatively slow growth index at 4,26 per year. However, the index is higher than that of other samples found in the waters of Eastern Indian Ocean and Eastern Coast of India. Mortality rates, be it natural and fishing mortality, fit into moderate category, while the exploitation rate was found extremely high. The extreme magnitude of exploitation attributes to the constraint that the recruits did not achieve their full potential.

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