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Some population parameters of *Rastrelliger* spp. from palaw and adjacent coastal waters, Taninthayi region in Myanmar

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Abstract
An investigation of the population parameters of *Rastrelliger brachysoma* and *R. kanagurta* in Palaw and adjacent coastal waters, Taninthayi Region was carried out from April 2017 to March 2018. Asymptotic length (L_∞), growth coefficient (K), age at zero length (t_0) and growth performance index (ϕ') were estimated 25.20 cm, 1.50 year^{1}, -0.109 year and 2.979 for the former species and 28.88 cm, 0.55 year^{-1}, -0.299 year and 2.662 for the second species. Total mortality (Z), natural mortality (M) and fishing mortality (F) were calculated 2.55 year^{-1}, 2.49 year^{-1} and 0.06 year^{-1} for *R. brachysoma* and 2.03 year^{-1}, 1.25 year^{-1} and 0.78 year^{-1} for *R. kanagurta*. Exploitation level (E) of *R. brachysoma* was found to be 0.02 and 0.38 for *R. kanagurta*. The length at first capture L_c was 14.39 cm with an age (t_c) of 0.4 year for *R. brachysoma* and 21.78 cm with an age (t_c) of 2.25 year for *R. kanagurta*. The length-weight relationship of *R. brachysoma* was observed as W=0.0274 $L^{2.7921}$, r=0.93, r^2=0.8671, a=-1.563, b=2.7921 for male and W=0.0553 $L^{2.5585}$, r=0.88, r^2=0.7718, a=-1.2575, b=2.5585 for female. The length-weight relationship of *R. kanagurta* was observed as W=0.0283 $L^{2.7738}$, r=0.92, r^2=0.8424, a=-1.5484, b=2.7738 for male and W=0.0912 $L^{2.3954}$, r=0.94, r^2=0.8927, a=-1.0399, b=2.3954 for female. Result showed that *R. brachysoma* and *R. kanagurta* had shown negative allometric growth because b values was less than 3 (b<3).

Keywords: Population parameters, *Rastrelliger brachysoma* and *R. kanagurta*

1. Introduction

Fish population biomass depends on the measurement of an individual weight of fish. Study on the fish population dynamics gives a clear picture of the life history pattern of a specific fish species [1]. Tropical fish population dynamics, then, can be more specifically defined as the set of methods which can be used quantitatively to interpret data on: 1) stock sizes, 2) recruitment, 3) growth and 4) natural mortality of tropical fish, such that potential catches can be predicted or such that existing fisheries can be knowledgeably managed [2]. Studies on population dynamics of fishes from tropical waters became popular after the formulation of length-based methods and models and the introduction of suitable computer software's like FiSAT. The use of length-based methods was also facilitated by the development of computer programs for this purpose by using the series of ELEFAN programs and World Fish stock assessment tools, namely FiSAT software which was regarded as inexpensive and rapid, yet providing reliable results [1, 2]. The study of length-weight relationship in fishes is of considerable importance in the fishery work. In nature, the body proportions of a fish continually change with aging. The form and specific gravity do not remain constant throughout the life history of the fish. Condition factor of fish in general is an expression of relative fatness of fish. The population parameters of the interesting fish stock, such as growth and mortality must be known to quantify the optimum fishing intensity, because they are the input parameters for the number of the stock assessment models [13]. The growth parameters obtain from fitting the observed growth data into the mathematical models are the basic data into the analytical models used in assessing and managing the status of the exploited fish stocks. Exploitation of marine fish demand studies directed towards understanding the population of the exploited stocks in space and time [14]. Fishery is the main occupation for the coastal people who live in Taninthayi Region. Palaw is a township in Taninthayi Region, southernmost part of Myanmar. Most local people conducted fishing from small scale to large scale since many years ago.

It provides enough fish food for local people and economically exploitable natural fishery resources. Nowadays, fish exploitation has been increasing at a very rapid rate to meet the growing demands of the rapidly multiplying human population which in turn has led to a drastic decline in the abundance of many fish stocks. Therefore, this study was intended to know the growth of the *Rastrelliger* spp from which length size distribution data, to estimate how fast the fish grow and the recovery times of its population after exploitation and to provide the basic information required to set a management strategy for the rational exploitation of valuable *Rastrelliger* species in Palaw and adjacent coastal waters.

2. Materials and Methods

Two species *Rastrelliger brachyosoma* and *R. kanagurta* of various lengths (cm) and weight (g) were randomly collected from the fishing boats and fish landing sites during April 2017 to March 2018. Fish from each fish sample was measured for its total length with measuring board and weighted in balance to calculate the length frequency distribution, length-weight relationship, condition factor, growth parameter and mortality parameter.

Sampling area	Location
1. Palaw	(Lat 12° 57' 57.70" N, Long 98° 37' 28.68" E)
2. Shat-pon	(Lat 12° 58' 19.25", N Long 98° 38' 37.72" E)
3. Ngar-kyun	(Lat 13° 2' 13.55", N Long 98° 19' 57.55" E)
4. Zayat-seik	(Lat 13° 6' 26.40" N, Long 98° 19' 38.10" E)
5. Pyin-bu-nge	(Lat 13° 7' 5.09" N, Long 98° 30' 17.90" E)
6. Pyin-bu-gyi	(Lat 13° 12' 1.70" N, Long 98° 26' 58.54" E)

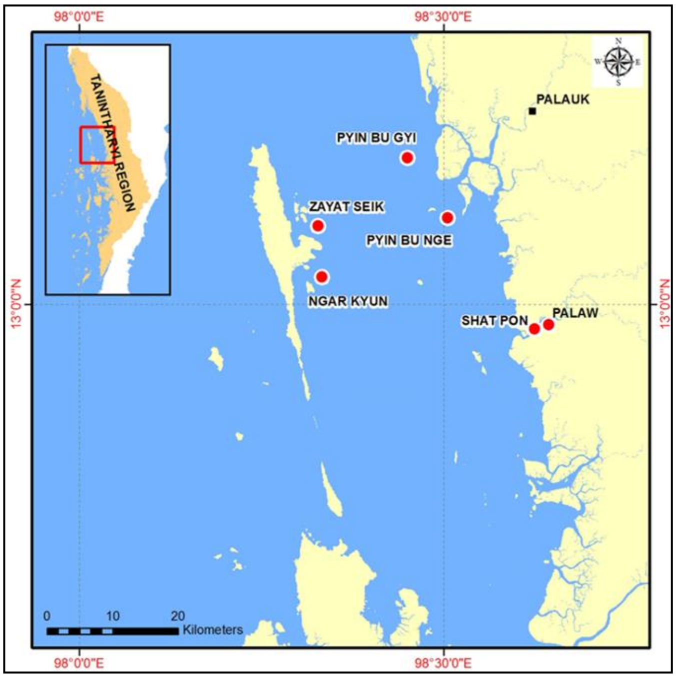

Fig 1: Map showing the study area from Palaw and adjacent coastal waters, Taninthayi Region

2.1. Length frequency distribution

A total of 2808 fish samples for *Rastrelliger brachysoma* was arranged into14 groups (class mid length 11-24 cm) with the class interval of 1 cm and 2288 samples for *Rastrelliger kanagurta* was arranged into 15 groups (class mid length 13.5-27.5 cm) with the class interval of 1 cm. And then, the mean value and standard deviation were computed by excel program.

2.2. Length-weight relationships

Length (cm) and Weight (g) measurement: Total length (from the tip of the anterior part of the mouth to the caudal fin) of each sample was measured to the nearest 0.1 centimeter by measuring board. Body weight was measured to the nearest 0.1 gram by balance. The growth of fish was determined from the resultant value of the exponent 'b'. When 'b' value equals 3, growth of fish is isometric. If the value of 'b' is larger or smaller than 3, growth of fish is allometric (positive allometric if b>3, negative allometric if b<3). The degree of association between length and weight variables was calculated by the determination of correlation coefficient (r). The parameters 'a' and 'b' of length-weight relationship of fish were estimated by the following formula [2, 3, 7, 8, 9]

$$W=\alpha L^{b}$$

where, W= weight of fishes, L= length of fishes, α= constant, b= the exponent

2.3. Condition Factor (k)

The condition factor (K) which indicates the condition of fish was calculated by the following formula [3, 7, 12]

$$K = \frac{W*100}{L^3}$$

where, K= condition factor, W= weight of fish (g), L= length of fish (cm)

2.4. Growth parameters

Growth parameters such as asymptotic length (L_∞), growth constant (K) values and growth performance index (ϕ') were obtained using the Von Bertanlaffy Growth Function (VPGF) fitted in FiSAT II. According to VPGF as expressed below, individual fishes grow on average towards the asymptotic length at an instantaneous growth rate (K) with length at time (t) following the expression [1,2,13]

$$L_t = L_\infty \left(1-e^{-K(t-t_0)}\right)$$

where, L_t= Fish length at age t, L_∞= an asymptotic length that is the mean length of fish would reach if they were to grow indefinitely, K= growth coefficient or rate at which L_∞ is approached, t_0 = theoretical age of fish at birth or age of the fish at zero length.

The inverse von Bertalanffy growth equation [1,2]: $t_{(L)}= t_0-1/K \ln (1-L/L_\infty)$ was used to convert length data into age data.

The length in cm at any age of an average fish of the stock can be calculated the von Bertalanffy growth equation [1, 2, 11, 12, 14]

$$L_t = L_\infty*(1-\exp(-K*(t+t_0))$$

The theoretical age at birth (t_0) was calculated independently, using the empirical formula [1, 2, 3, 16]

$$\text{Log}_{10}(-t_0) = - 0.3922 - 0.275* \text{Log}_{10} L_\infty - 1.0381* \text{Log}_{10} K$$

The longevity (T_{max}) was estimated [2] $T_{max} = 3/K+t_0$

where, t_{max}= the approximate maximum age of fish would reach

To compare the growth rate of the fish species for this study with published values, the growth performance index was

generated as expressed in the equation [2, 3, 4, 9, 13]
$ø = 2 \log L_\infty + \log K$

2.5. Mortality parameters
A linearized length-converted catch curve was constructed using the following formula to estimate the total mortality (Z) [1,2].

$$\ln (N_i/\Delta t) = a + bt$$

Where N_i = number of individuals fish in a given length class interval, Δt = the time needed for a fish to grow through length class interval, a= intercept, b= slope of the curve which gives an estimate of the value Z and t = the age corresponding to the mid length of the certain length class interval.
Natural mortality rate (M) was computed by the empirical equation [1, 2, 9, 11]

$$\log M = -0.0066 - 0.279 \log L_\infty + 0.6543 \log K + 0.4634 \log T$$

where, M= natural mortality, L_∞= asymptotic length, K= growth curvature and T= the mean annual habitat water temperature °C (the mean sea surface temperature as 27°C). In the present study, mean temperature was taken as (29.3 °C).
Fishing mortality (F) was calculated using the relationship [1, 2, 9, 14]

$$F = Z - M$$

where F= fishing mortality, Z= total mortality and M= natural mortality.

2.6. Exploitation rate (E)
It refers to the ratio between fish caught and the total mortality (Ricker, 1975) or the exploitation rate or fraction of death caused by fishing (Sparreand Venema, 1992). It is estimated by the equation [1, 2, 9, 11]

$$E = F/Z = F/(M+F)$$

The ratio gives an indication of the state of exploitation of a stock under the assumption that the optimal value of E equals 0.5 (E = 0.5). This, in turn, is under the assumption that the sustainable yield is optimized when F=M [1,16].

2.7. Length at first capture (L_{50})
To identify the fishing regime, the length at first captures (Lc_{50}) (length at which 50% of fishes caught) was estimated. The ascending left arm of length-converted catch curve incorporated in FiSAT II tool was used to estimate the probability of length at first capture (Lc_{50}) in addition to the length at both 25 and 75 captures which corresponded to the cumulative probability at 25% and 75% respectively.

2.8. Virtual Population Analysis (VPA)
A virtual population denotes the exploited population, and the analysis estimates the population that must have been present to produce the catch. From the observations on the number caught in each age/length group and from independent estimates of the natural mortality, the length-based cohort analysis (VPA) estimates how many fish there must have been in the sea to account for that catch [2].

3. Results and Discussion
3.1. Length frequency distribution
Two fish species: *Rastrelliger brachysoma* (2808) and *Rastrelliger kanagurta* (2288) were used to conduct for the determination of the abundance (frequency) of fish with respect to size (length). The length frequency data of *Rastrelliger* species ranging the size group of total length for *R. brachysoma* 10.5 to 24.0 cm and for *R. kanagurta* 13.0 to 27.0 cm were collected during the study period.
The length frequency of smallest size of *R. brachysoma* was observed as 10.5 cm in June and the largest size of 24 cm was observed in April and July in total length (TL). The most abundance caught was 16.5-19.5 cm size group and 10.5 cm size group was rarely found.
The length frequency of smallest size of *R. kanagurta* was observed as 13 cm in July and the largest size of 27.0 cm was observed in January in total length (TL). The most abundance caught was 20.0-22.0 cm size group and 13.0 cm and 26.0-27.0 cm size group were rarely found. Monthly length frequency data is presented in Figure 2 and 3.

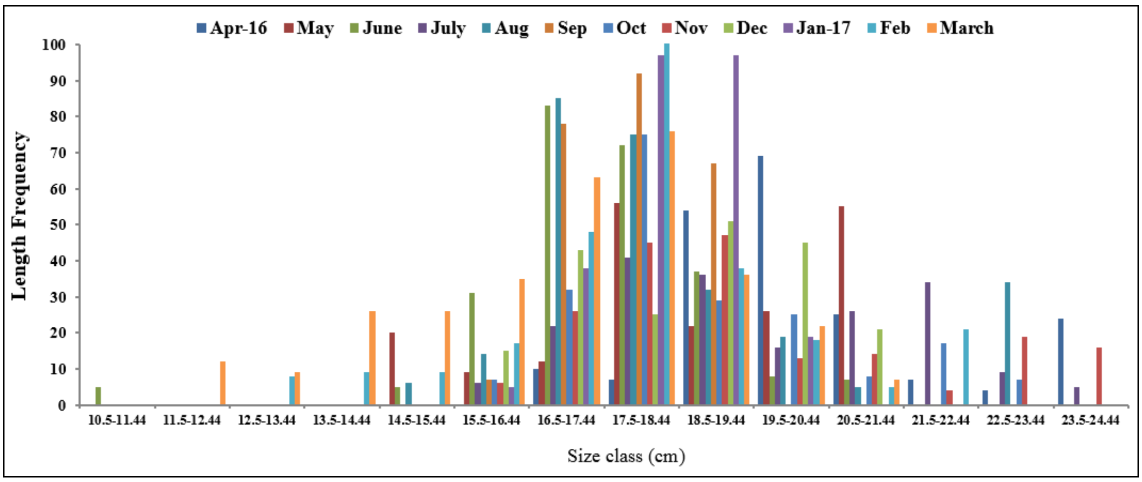

Fig 2: Monthly length frequency distribution of *Rastrelliger brachysoma*

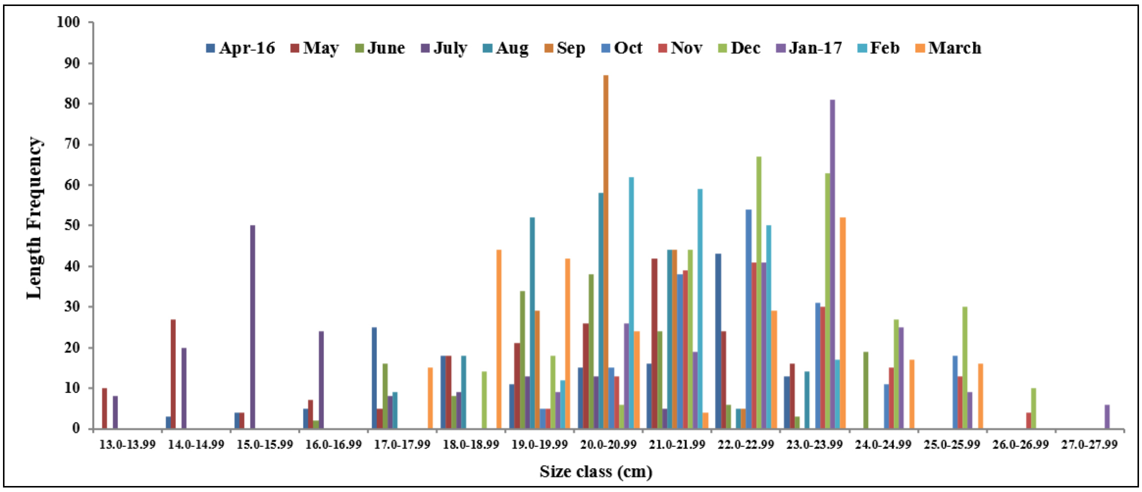

Fig 3: Monthly length frequency distribution of *Rastrelliger kanagurta*

3.2. Length-weight relationships

A total of 237 male (16-23.5 cm, TL) with mean length of 18.80±1.31 cm and 248 females (15.5- 24 cm, TL) with a mean length of 18.77±1.29 cm of *Rastrelliger brachysoma* were used to estimate their length-weight relationships in this study. The mean weight of the male (100.25±21.82 g) and that of female (101.52±21.45 g) were observed. The exponent 'b' value of male was 2.79 and that of female was 2.55 respectively. The length-weight relationships of male and female of *Rastrelliger brachysoma* are shown in Figure 4.

$W = 0.0274\ L^{2.7921}$, r = 0.93 (male)
$W = 0.0553\ L^{2.5585}$, r = 0.88 (female)

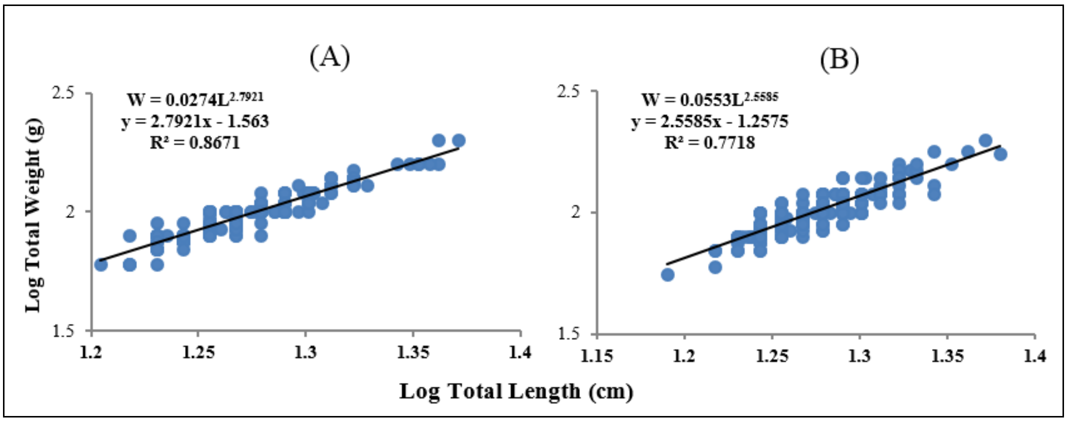

Fig 4: Length weight relationship of *Rastrelliger brachysoma* A) male and B) female

In *Rastrelliger kanagurta*, 325 male (14.5-25 cm, TL) with mean length of 21.03±1.35 cm and mean weight of the male (133.71±24.88 g) and 107 female (17.5-24cm, TL) with a mean length of 21.82±1.91 cm and mean weight of the female (149.3±32.87 g) were observed for this analysis. The exponent 'b' value of male was 2.77 and that of female was 2.39 respectively. Length-weight relationships of male and female of *Rastrelliger kanagurta* are presented in Figure 5.

$W = 0.0283\ L^{2.7738}$, r = 0.92 (male)
$W = 0.0912\ L^{2.3954}$, r = 0.94 (female)

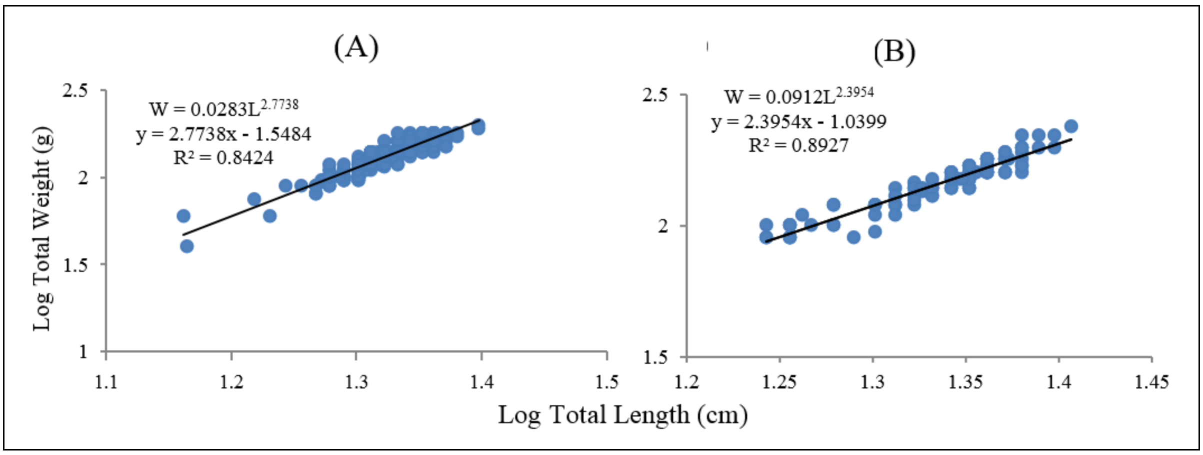

Fig 5: Length weight relationship of *Rastrelliger kanagurta* A) male and B) female

The value of exponent (b) for male *Rastrelliger kanagurta* was 2.77 and for female was 2.39 in the present study. The resultant 'b' value of both male and female indicated that negative allometric pattern. This result was similar with the previous finding of Honey Shwe [6]. Rahman and Hafzath [7] from the Kuntan coastal area and Ahmed *et al.* [8] from Karachi fish harbour showed that male of *R. kanagurta* was significantly more than female in the population. Both male and female of 'b' values were observed only negative allometric growth that was the same in the present study.

3.3. Condition factor (K)
Condition factor (K) which is the ratio between total mean length and weight was calculated for males and females of *R. brachysoma* and *R. kanagurta* and represented in Table 1. In *Rastrelliger brachysoma*, the condition factor was from 1.39 to 1.71 in males with the mean value of 18.80±1.31 cm and with the mean weight of 100.25±21.82 g and 1.31 to 1.93 in females with the mean value of 18.76±1.29 cm and with the mean weight of 101.52±21.45 g. The value was high in October (1.71) and low in August (1.39) for males and high in the months of October (1.93) and low in the months of June (1.31) for females.

Table 1: Condition factor of male and female (*R. brachysoma* and *R. kanagurta*) in different months from Palaw and adjacent coastal water

Month	Rastrelliger brachysoma		Rastrelliger kanagurta	
	Male	Female	Male	Female
April (2017)	1.46	1.53	1.42	1.38
May	1.53	1.57	1.54	1.46
June	1.43	1.31	1.34	1.29
July	1.4	1.4	1.31	1.39
August	1.39	1.49	1.43	1.38
September	1.52	1.67	1.45	1.38
October	1.71	1.93	1.58	1.68
November	1.59	1.59	1.54	1.59
December	1.43	1.4	1.47	1.48
January (2018)	1.59	1.64	1.46	1.42
February	1.57	1.5	1.27	1.36
March	1.56	1.65	1.38	1.45

The range of condition factor for *Rastrelliger kanagurta* was 1.27-1.58 in males and 1.29-1.68 in females. The mean K values were 21.03±1.35 cm with the mean weight of 133.71±24.88 g in males and 21.82±1.91 cm with the mean weight of 149.34±32.87 g in females. The highest condition factor value in males was recorded in October (1.58) while lowest value was in February (1.27). For females, the value was high in October (1.68) and low in June (1.29).

3.4. Growth parameters
Asymptotic length (L_∞) and growth coefficient (K) calculated by connection the monthly length frequency data. A total of 2808 fish samples of *Rastrelliger brachysoma* ranging from 10.5 cm to 24 cm were collected for the age and growth studies. The growth parameters were estimated L_∞=25.20 cm and K=1.50 year^{-1} (Figure 6 A and B). Growth performance index (ϕ′) and the theoretical age at birth (t_0) were estimated at 2.979 and -0.109 years, respectively. Using the estimated growth parameters (L_∞, K and t_0), the VPGF for length at time (t) was expressed as:

$$L_t = 25.20\ (1\text{-}e^{-1.50\ (t-(-0.109))})$$

So, the *Rastrelliger brachyosoma* species may grow 14.95 cm in 0.5 year, 20.36 cm in 1.0 year, 22.91 cm in 1.5 year, 24.12 cm in 2.0 year from the theoretical age of fish at birth in its life. The longevity of *Rastrelliger brachysoma* (T_{max}) was 1.89 years. The observed extreme length was 24.0 cm and the predicted extreme length was 25.22 cm (Figure 6.C). The estimated recruitment pattern of *Rastrelliger brachysoma* was continuous with two peaks per year (Figure 6.D). Virtual population analysis (VPA) performed on *Rastrelliger brachysoma* indicated that main loss in the stock up to 16.4 cm size was due to natural causes. Fishes became more vulnerable to the gear after this size and mortality due to fishing increased and eventually out-numbered the natural losses from 22.0 cm onwards. Maximum fishing mortality was recorded at size of 23.4 cm (Figure 6.E).
A total of 2288 samples of *Rastrelliger kanagurta* in the length range of 13 cm to 27 cm were used monthly for the estimation of growth parameters. The growth parameters, L_∞=28.88 cm and K=0.55 year^{-1} were obtained by von Bertalanffy Growth Equation (VBGE) (Figure 7 A and B). The growth performance index, (ϕ′) was 2.662 and estimated t_0 value was -0.299. The growth parameters (L_∞, K and t_0) of *Rastrelliger kanagurta* for length at time (t) was expressed as:

$$L_t = 28.88\ (1\text{-}e^{-0.55\ (t-(-0.299))})$$

Rastrelliger kanagurta may grow 9.22 cm in 0.5 year, 13.95 cm in 1.0 year, 17.54 cm in 1.5 year, 20.16 cm in 2.0 year, 23.33 cm in 2.5 year and 23.91 cm in 3.0 year respectively in its life. Longevity for *Rastrelliger kanagurta* was 5.15 years. The observed extreme length was 27.50 cm and the predicted extreme length was 28.24 cm (Figure 7.C). The estimated recruitment pattern of *Rastrelliger kanagurta* showed two peaks per year (Figure 7.D). Virtual population analysis (VPA) performed on *Rastrelliger kanagurta* indicated that main loss in the stock up to 20.5 cm size was due to natural causes. Fishes became more vulnerable to the gear after this size and mortality due to fishing increased and eventually out-numbered the natural losses from 24.5 cm onwards. Maximum fishing mortality was recorded at size of 27.5 cm (Figure 7.E).

3.5. Mortality parameters
The total mortality coefficient (Z) of *Rastrelliger brachysoma* calculated by length-converted catch curve method was 2.51 year^{-1} (Figure 8.A). The natural mortality coefficient (M) was 2.49 year^{-1} and the fishing mortality coefficient (F) was 0.06 year^{1}. The exploitation rate (E) of this species was 0.02. The length at first capture (Length at which 50% of the fish are vulnerable to capture) was estimated at 14.39 cm TL, which corresponds to an age (t_c) of 0.4 year^{1} (Figure 8.B).
The total mortality estimate (Z) value for *Rastrelliger kanagurta* was 2.03 year^{-1} and the natural mortality value of (M) was 1.25 year^{-1} (Figure 9.A). The fishing mortality coefficient (F) was 0.78 year^{-1}. The exploitation rate (E) of this species was 0.38. Estimate of length at first capture was observed 21.78 cm TL, which corresponds to an age (t_c) of 2.25 year (Figure 9.B).

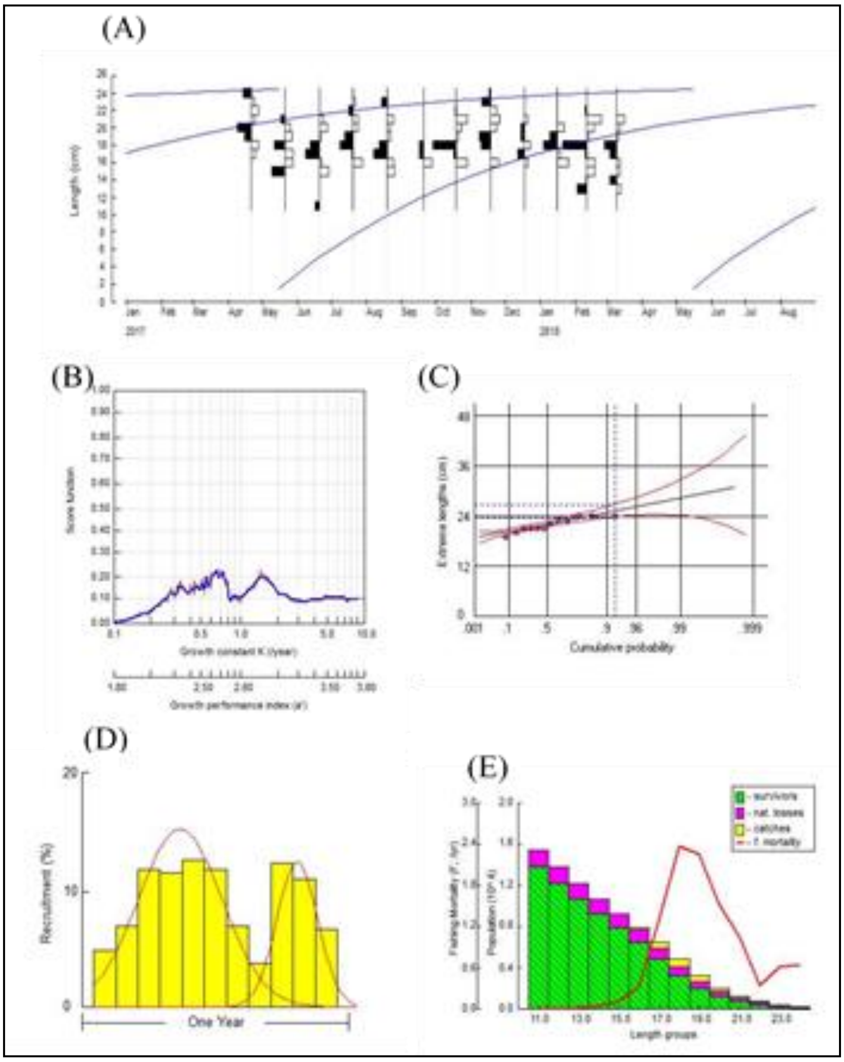

Fig 6: Estimated growth parameters of *Rastrelliger brachysoma*: A) Restructured vonBertalanffy growth curve, B) K estimation, C) Maximum length estimation, D) Recruitment pattern and E) Virtual Population analysis curve

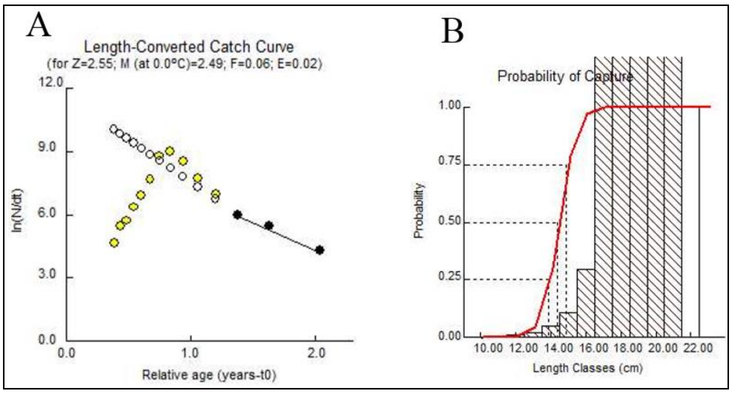

Fig 8: Estimated mortality parameters of *Rastrelliger brachyosoma*: A) Length-converted catch curve, B) Probability of capture

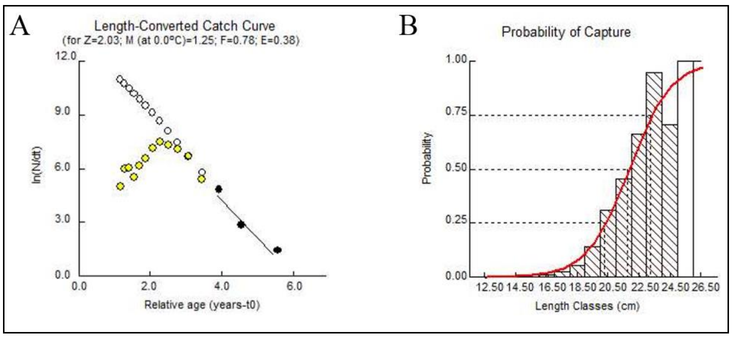

Fig 9: Estimated mortality parameters of *Rastrelliger kanagurta*: A) Length-converted catch curve, B) Probability of capture

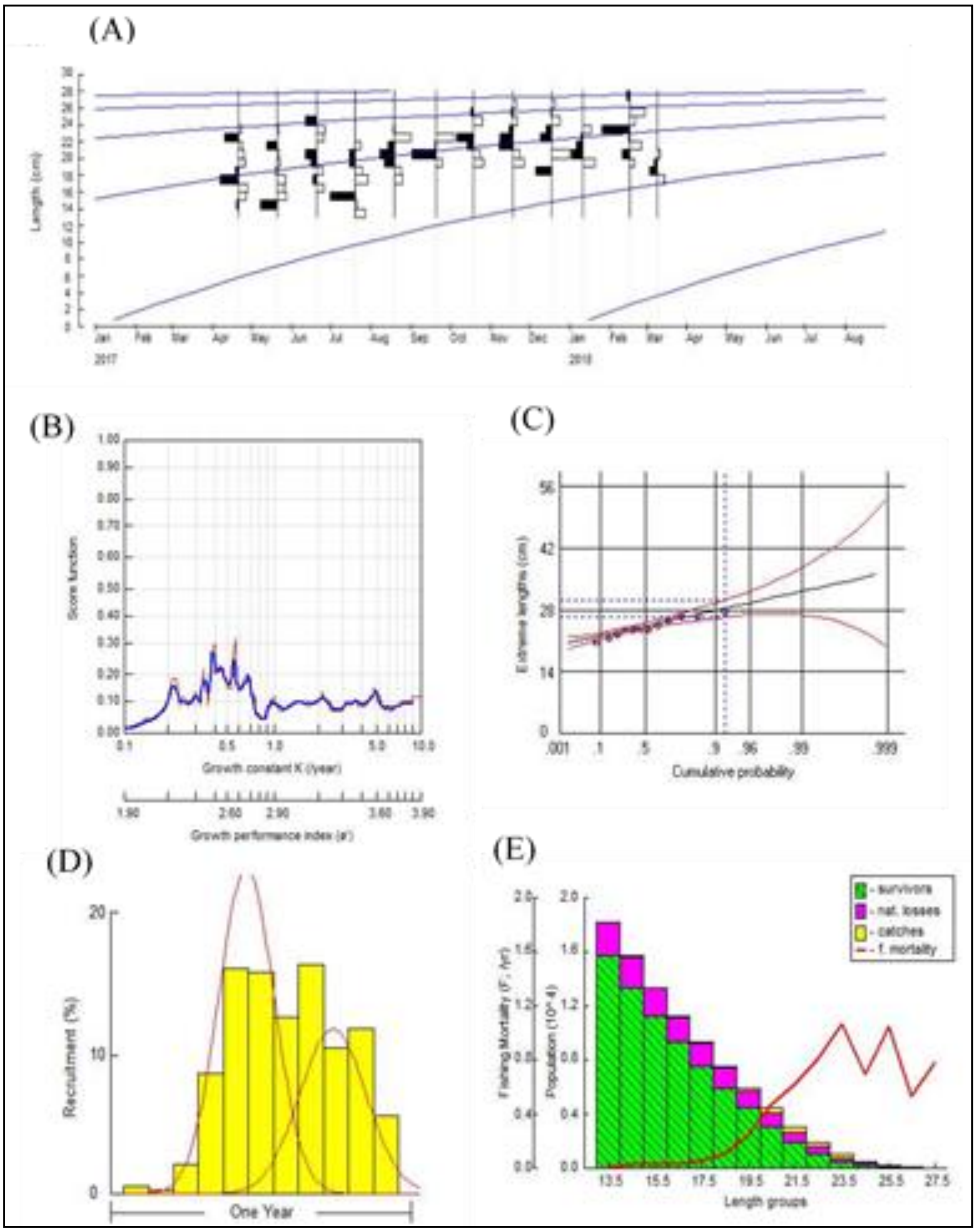

Fig 7: Estimated growth parameters of Rastrelliger kanagurta. A) Restructured vonBertalanffy grow curve, B) K estimation, C) Maximum length estimation, D) Recruitment pattern and E) Virtual Population analysis curve

In general, growth parameters need to be checked for the quality and validity. A positive value t_0 is often erroneous while a negative close to zero value of t_0 is a good indicator for the reliability of the determined ages. The value of theoretical age at length zero in the present study were (t_o=-0.109) for *R. brachysoma* and (t_o=-0.299) for *R. kanagurta*. The longevity (T_{max}) was estimated as 1.98 years for *R. brachysoma* and 5.15 years for *R. kanagurta*. Generally, there is a high correlation between growth rates (K) and (L_∞). Fishes with higher growth coefficient have higher natural mortality and shorter life span. Hence in this study the larger L_∞ and lower growth coefficient indicate lower natural mortality and longer life span. In the present study, the growth rate of *R. brachysoma* is the best within one year. After one year, the growth was gradually slow. *R. kanagurta* is the best during one year and two year. The growth was gradually slow later two years. According to Ghosh *et al.* [10] along the north-east coast of India, life span of *R. kanagurta* was (2.48 years) during their study period. This result was not similar with the present result because the longevity of *R. kanagurta* was a little high in Palaw and adjacent coastal water.

The recruitment curve of both *Rastrelliger kanagurta* and *R. brachysoma* indicated that the recruitment to the fishery takes place in two peaks, a prominent one, with the duration of six months and a minor one with a short duration of four months in the present study. This finding was similar for the former species with the previous study of Mustafa and Shahadat [11] from the Bay of Bengal. They suggested two seasonal pulses one in September-October and another in February-March. Peak recruitment appeared in September-October. However, Ghosh *et al.* [10] reported that recruitment takes place one peak. Peak recruitment was found to be during September-October.

The length at first capture (L_c) was estimated from probabilities of capture generated from the catch curve analysis. The estimated size of *R. brachysoma* of probability of capture (L_c) was 14.39 cm, which corresponds to an age (t_c) of 0.4 year. The present estimated length and age at first capture were 21.78 cm and 2.25 year for *R. kanagurta*. The present result of *R. brachysoma* was lower when compared to 19.5 cm as reported by Pauly and Sann Aung [5] from the southern coast of Myanmar, Myeik Archipelago. The present length at first capture of *R. kanagurta* was higher when compared to 18.09 cm presented by Mustafa and Shahadat [11] from the Bay of Bengal. But, the previous study of Koolkalya *et al*. [13] from the Eastern Gulf of Thailand estimated (L_c) was 21 cm. So, the previous and present studies were nearly similar. The recruitment pattern of *Rastrelliger brachysoma* was presented twice a year in Myeik Archipelago, Burma. This result was similar with the present study.

The exploitation ratio (E) is an index to assess if a stock is overfished, on the assumption that optimal value of E is equal to 0.50. The exploitation ratio (E) will be than 0.5 for the stocks supposed to be over fished [11, 15]. The present exploitation rate was estimated as 0.02 for *R. brachysoma*. Pauly and Sann Aung [5] reported that the over-explotation of *R. brachyosoma* with a high values of exploitation rate (E=0.79). The previous estimate on exploitation rate of *R. brachysoma* species indicated that was being over-exploited at a higher level than the optimal level in 1996-1998 of Myeik Archipelago by Pauly and Sann Aung [5]. The present exploitation rate (E) estimated as 0.38 for *R. kanagurta*. Based on these values, *R. kanagurta* was the optimum level of exploitation in the present study. The results from this present study gave information that these two species not heavy exploitation exists within the Scombrids fishery in Palaw coastal waters.

4. Conclusion

This study provided basic information on the population parameters of length frequency distribution and length-weight relationship of *Rastrelliger brachysoma* and *R. kanagurta* that are useful for fishery management. According to length frequency distribution, the juveniles were also observed throughout the study period. The dominance of medium and large size fish observed in a year-round may be supposed that the *Rastrelliger* species could breed throughout the year. The growth and mortality parameters provide an important guideline for fisheries management of these species. However, a detailed study on reproductive biology is needed for proper management of fishery stock of this commercially important fish species.

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