Population Parameters of *Rastrelliger kanagurta* (Cuvier, 1816) in the Marudu Bay, Sabah, Malaysia

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Abstract

An investigation of the population parameters of Indian mackerel, *Rastrelliger kanagurta* (Cuvier, 1816) in the Marudu Bay, Sabah, Malaysia was carried out from January to September 2013. The relationship between total length and body weight was estimated as $W=0.006TL^{3.215}$ or Log W=3.215LogTL – 2.22 (R^2=0.946). Monthly length frequency data of *R. kanagurta* were analyzed by FiSAT software to evaluate the mortality rates and its exploitation level. Asymptotic length (L_∞) and growth co-efficient (K) were estimated at 27.83 cm and 1.50 yr^{-1}, respectively. The growth performance index (φ') was calculated as 3.07. Total mortality (Z), natural mortality (M) and fishing mortality (F) was calculated at 4.44 yr^{-1}, 2.46 yr^{-1} and 1.98 yr^{-1}, respectively. Exploitation level (E) of *R. kanagurta* was found to be 0.45. The exploitation level was below the optimum level of exploitation (E=0.50). It is revealed that the stock of *R. kanagurta* was found to be still under exploited in Marudu Bay.

Keywords: Population parameters, *Rastrellier kanagurta*, Marudu Bay, Sabah, Malaysia.

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Introduction

Indian mackerel, scientifically known as *Rastrelliger kanagurta* (Cuvier, 1816) enjoys wide distribution around the world and has good domestic demand as a food fish. Among the variety of marine fish species, Indian mackerel is one of important fish in Malaysia. It is locally familiar as “Kembung” and commercially important fish marketed mostly fresh, salted, smoked and dried on the coast of Malaysia (Rumpet et al., 1997; Ambak et al., 2010). Low market price, high abundance and ease in the capture were the main reasons for their popularity as food fish among Malaysians (Rahman and Hafzath, 2012). In 2010, the total production of *R. kanagurta* from Malaysia coastal waters was estimated about 186,225 metric tonnes and it includes 10% of total capture fish production (Ambak et al., 2010).

Morphologically, *R. kanagurta* has bluish green body with dark stripes or rows of dusky spots along upper half of the body, two dorsal fins, the first being spiny and the second one rayed, 5-6 pairs of anal finlets, pelvic fin without spine, snout pointed and length of head distinctly greater than depth of body (Ganga, 2010). These physical characteristics are used to distinguish this species from another species (*R. brachysoma*). The eggs and fish larvae of *R. kanagurta* are pelagic with the eggs fertilized externally by the brood stocks (Collette, 2001). Spawning usually occur in several batches. Mature *R. kanagurta* generally consume macro plankton such as larval shrimps and fish as their main diet (Rao and Rao, 1957).

It is widely distributed in Indo-West Pacific, from South Africa and Red Sea to Samoa, north to southern Japan (Luther, 1995). The habitat of this marine fish is shallow coastal waters with depth range of 20-90 m (Pauly et al., 1996). The commercial importance of *R. kanagurta* derives from the use and potential of this fish as a food organism for aquaculture industry (Abdussamad et al., 2006). High availability of schools of *R. kanagurta*, particularly in Asian waters is also the bases of important commercial fishes for consumption by humans (Noble et al., 1992; Devaraj et al., 1994; Rohit et al., 1998). Both features make *R. kanagurta* as a good candidate for population dynamics study. No information is available on the population dynamics of *R. kanagurta* in Malaysia so far in spite of greater abundance except the studies carried out elsewhere by Rao and Rao (1957), Luther (1995), Pauly et al. (1996), Collette (2001), Mehanna (2001), Rohit and Gupta (2004), Ganga (2010), Abdussamad et al. (2010) and Rahman and Hafzath (2012).

The knowledge in population dynamics and stock status of certain species is necessary for the planning and management of fish stock. Among the tools in estimating stock status and exploitation level of fish, the FiSAT (FAO-ICLARM Stock Assessment Tools) are widely used (Amin et al., 2001; Amin and Zafar, 2004; Mateus and Estupiñán, 2002; Allam, 2003; Jaiswar et al., 2003; Abdussamad et al. 2010; Francis and Samuel, 2010), because it is a friendly and simple package that can be handled easily. Several important population parameters such as asymptotic length (L_∞) and growth coefficient (K), mortality (natural and fishing) rate and exploitation level (E) can be analyzed by using FiSAT. Realizing the importance of *R. kanagurta* in the coastal waters, the studies were conducted on the population dynamic of *R. kanagurta* in the Marudu Bay, Sabah, Malaysia to estimate the population parameters and to evaluate the stock status of *R. kanagurta* in Marudu Bay, Sabah, Malaysia.

Materials and methods

The study was conducted in the coastal waters of Marudu Bay, Sabah, East Malaysia (Fig. 1). Monthly sampling was carried out between January and September 2013. Five sampling stations were selected for this study. The location of the sampling stations were as St. 1 (N 06º 36.169' E 116º 46.400'), St. 2 (N 06º 36.651' E 116º 48.895'), St. 3 (N 06º 36.700' E 116º 47.775'), St. 4 (N 06º 36.751' E 116º 47.816') and St. 5 (N 06º 37.502' E 116º 47.775'). Sampling stations were approximately 1 km apart from each other (Fig 1). Fish samples were caught by using gill net. The dimensions of the net were 140 - 150 m in length and 1.0 - 1.5 m in width. The net was divided by five sections that were attached together side by side. The mesh size was different in five sections. The mean mesh sizes were 1.25 (±0.01) inches in the first section, 1.50 (±0.01) inches in the second section, 1.75 (±0.02) inches in the third section, 2.00 (±0.02) inches in the fourth section and 2.50 (±0.02) inches in the fifth section. After collection, the fresh samples were immediately preserved in ice chest (Arshad et al., 2008).

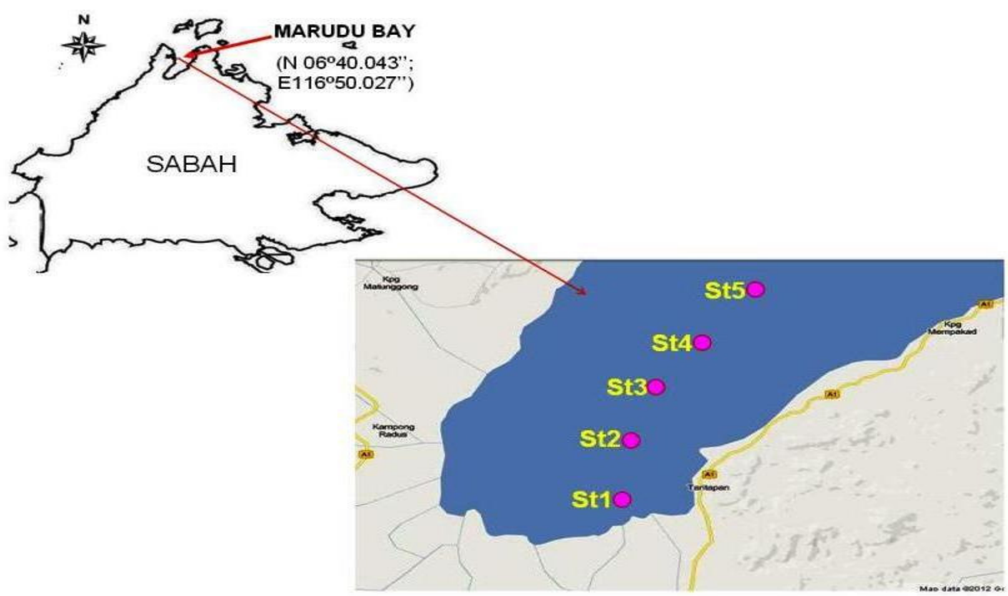

Figure 1: Geographical location of the sampling stations in the Marudu Bay, Sabah, Malaysia.

Total lengths of 660 individuals were measured using a digital caliper to the nearest 0.1 mm and total weight was taken by an electronic balance of 0.001 g accuracy.

The commonly used relationship $W = aL^b$ was applied to establish the length-weight relationship (Ricker, 1975; Quinn and Deriso, 1999) where W is the weight (g), L is the total length (mm), a is the intercept and b is the growth slope (growth coefficient). The parameters a and b were estimated by least squares linear regression on log–log transformed data: $\log_{10} W = \log_{10} a + b \log_{10} L$. The coefficient of determination (r^2) was used as an indicator of the quality of the linear regression (Scherrer, 1984). Additionally, the statistical significance level of r^2 and 95% confidence limits of the parameters a and b were estimated.

Monthly length-frequency data (Table 1) were analysed using the FiSAT computer programme (Gayanilo et al., 1996). Asymptotic length (L_∞) and growth coefficient (K) of the von Bertalanffy growth function (VBGF) was calculated by using ELEFAN-1 (Pauly and David, 1981). In order to assess a reliable estimate of the K value, K-scan was conducted. The estimates of L_∞ and K were used to estimate the growth performance index (φ) (Pauly and Munro, 1984) of the specimens by using the equation:

$$\varphi' = 2 \log_{10} L_\infty + \log_{10} K$$

Table 1: Monthly length frequency data of *R. kanagurta* in the Marudu Bay, Sabah, Malaysia, during January 2013 to September 2013

ML	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
11.5			3	3	10			1	
12.5	1		24	33	9	2		4	
13.5	1		54	26	1	7		2	
14.5	1		11	2	4	50	1	2	
15.5	2				10	13	2	1	
16.5	15	5			25	2	6	6	
17.5	35	13			12	37	27	10	
18.5	8	11			1	7	83	20	
19.5	1	1				3	9	7	
20.5							1		1
21.5									9
22.5									5
23.5					2				8
24.5					2				
25.5					6				
26.5					1				

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Total mortality (Z) was estimated using the length converted catch curve (Pauly, 1984) and the natural mortality rate (M) was estimated by using empirical relationship of Pauly (1980):

$Log_{10}M = -0.0066 - 0.279 \log_{10}L\infty + 0.6543 \log_{10}K + 0.4634 \log_{10}T$

where M is the natural mortality, L_∞ the asymptotic length, K the growth coefficient of the VBGF and T is the mean annual habitat water temperature. Once Z and M was obtained, then fishing mortality (F) was estimated using the relationship:

$F = Z - M$

where Z is the total mortality, F is the fishing mortality and M is the natural mortality. The exploitation level (E) was obtained by the relationship of Gulland (1965):

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

The backward projection on the length axis of the set of available length–frequency data as described in FiSAT was used in determining the recruitment pattern of *R. kanagurta*. The number of pulses per year and the relative strength of each pulse determined by this routine that reconstructs the recruitment pulse from a time series of length–frequency data. Input parameters were L_∞, K and t_0 (t_0 = 0). Normal distribution of the recruitment pattern was determined by NORMSEP (Pauly and Caddy, 1985) in FiSAT.

The estimated length structured virtual population analysis (VPA) and cohort analysis was carried out from the FiSAT routine. The values of $L_{\infty,}$ K, M, F, a (constant) and b (exponent) were used as inputs to a VPA analysis. The t_0 value was taken as zero. The method was published by Fry (1949) and subsequently modified by many authors. Practical reviews of VPA methods were, among others given by Pauly (1984) and Jones (1984).

Results

The length weight relationship (LWR) curve is presented in arithmetic scale in Fig. 2. The LWR of *R. kanagurta* was established as log Log W= 3.215 Log TL – 2.22 (R^2 = 0.946). In power form the equation was W= $0.006TL^{3.215}$ (R^2 = 0.946). The calculated growth coefficient *b* was 3.215 ($p<.05$) and the constant *a* was 0.006. The LWR of *R. kanagurta* indicated positive allometric growth in the study area.

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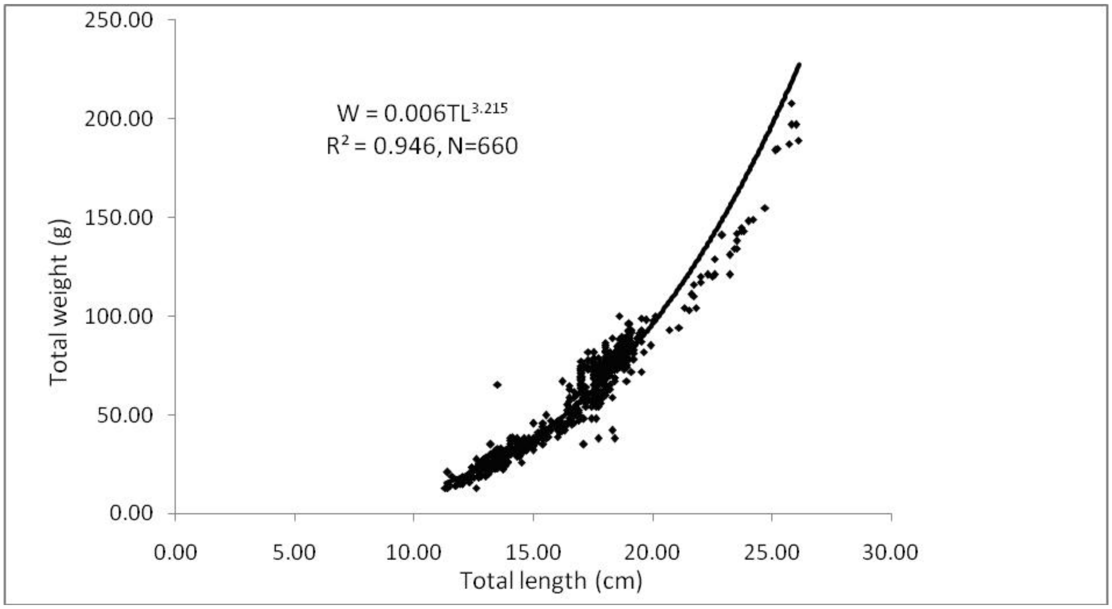

Figure 2: Length-weight relationship of *R. kanagurta* in the Marudu Bay, Sabah, Malaysia

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The observed and the predicted extreme length (L_{max}) were found to be 26.50 and 26.19 cm respectively (Fig. 3). The range at 95% confidence interval for extreme length was calculated as 25.54 – 27.58 cm. This initial extreme length value was used into ELEFAN-I, incorporated in FiSAT package producing the optimum growth curve. The best value of VGBF growth constant (K) was estimated as 1.50 yr^{-1} by ELEFAN-I (Fig. 4). The response surface (Rn) was calculated as 0.342 which selected the best combination of growth parameters L_∞ = 27.83 cm and K = 1.50 yr^{-1}. The optimized growth curve was superimposed on the restructured length-frequency histograms (Fig. 5). The calculated value for the growth performance index (φ') of *R. kanagurta* during the present investigation was 3.07.

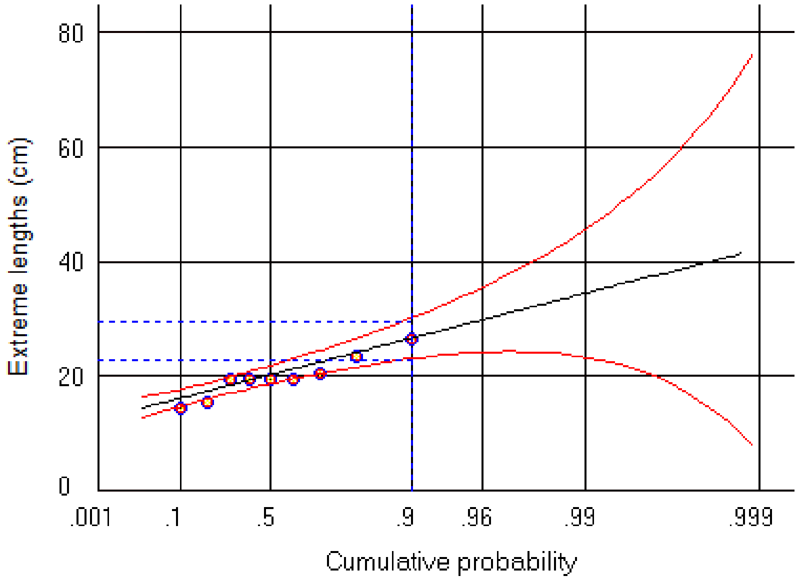

Figure 3: Predicted maximum length for *R. kanagurta* based on extreme value theory. The predicted maximum length value and the 95% confidence interval are obtained from the intersection of overall maximum length with the line y and x, z respectively

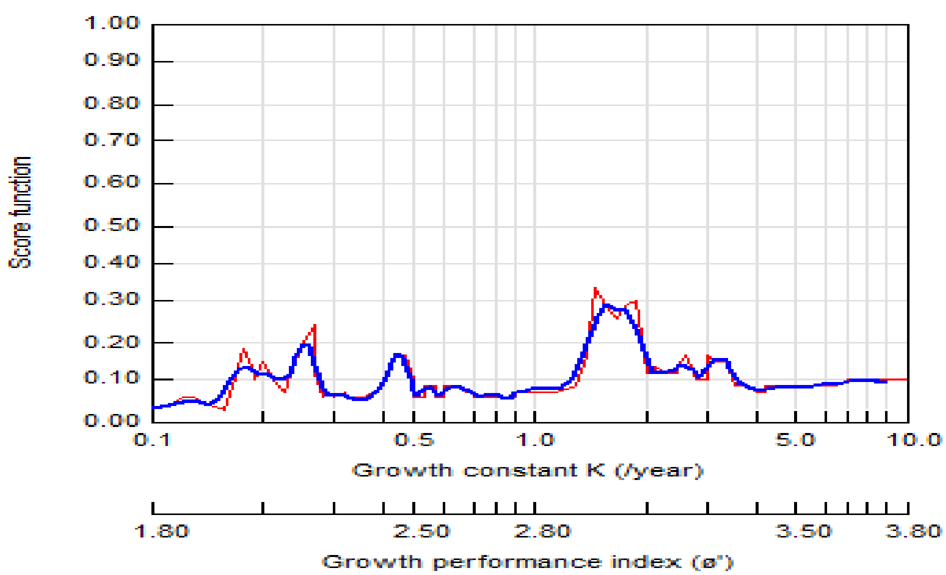

Figure 4: K-scan routine for the best value of von Bertalanffy growth function (VBGF), asymptotic length (L_∞) and growth co-efficient (K) of *R. kanagurta* using the ELEFAN-1

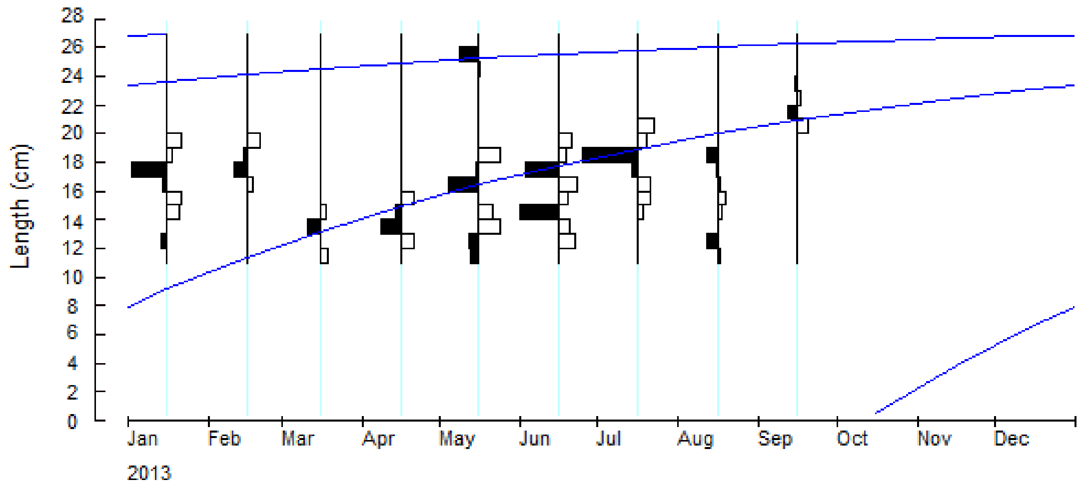

Figure 5: von Bertalanffy growth curve of *R. kanagurta* superimposed on the restricted length-frequency histogram. (L_∞ = 27.83 cm and K = 1.50 yr^{-1}). The black and white bars are positive and negative deviation from the "weighted" moving average of three length classes and they represent pseudo-cohorts.

Total mortality coefficient (Z) was estimated as 4.44 yr^{-1} using length converted catch method (Fig. 6). Natural mortality (M) was estimated at 2.46 yr^{-1}. Based on Z, fishing mortality (F) was found to be 1.98 yr^{-1} (Table 2). The exploitation rate (E) was calculated at 0.45 (Table 2). The fishery in the coastal waters of Marudu Bay, Sabah was seemed to be lower than the optimum level of exploitation (E = 0.50).

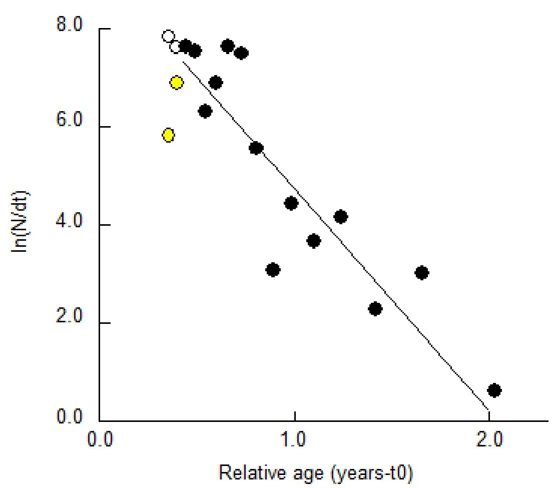

Figure 6: Length converted catch curve of *R. kanagurta* in the Marudu Bay, Sabah, Malaysia

Table 2: Estimated population parameters of *R. kanagurta* in Marudu Bay, Sabah, Malaysia

Population parameters	Result
Asymptotic length (L_∞) in cm	27.83
Growth co-efficient (K yr^{-1})	1.50
Growth performance index (φ')	3.07
Natural mortality (M yr^{-1})	2.46
Fishing mortality (F yr^{-1})	1.98
Total mortality (Z yr^{-1})	4.44
Exploitation level (E)	0.45
Sample number (N)	660

The recruitment pattern of *R. kanagurta* was continuous throughout the year with 2 major peaks (Fig. 7). The recruitment varied from 5.23 to 40.12% during the study period. The highest recruitment was occurred in the relative month 8 (August) and the lower recruitment was observed in the months 1 (January), 2 (February), 5 (May) and 6 (June) (Fig. 7).

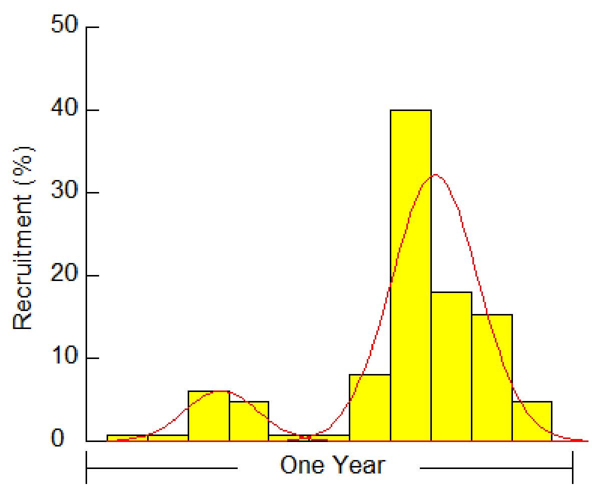

Figure 7: Recruitment pattern of *R. kanagurta* in the Marudu Bay, Sabah, Malaysia

Virtual population analysis (VPA) performed on *R. kanagurta* indicated that the minimum and maximum fishing mortalities were recorded for the mid lengths as 0.22 yr^{-1} and 4.66 yr^{-1}, respectively (Fig. 8). The fishing mortality (F) was comparatively high over the mid lengths between 14 and 18 cm. This increase was a reflection of recruitment over this length range rather than increased efficiency of the gear with length. F reached a maximum of 7.18 yr^{-1} at 18.5 cm with an average value of 1.87 yr^{-1} through VPA.

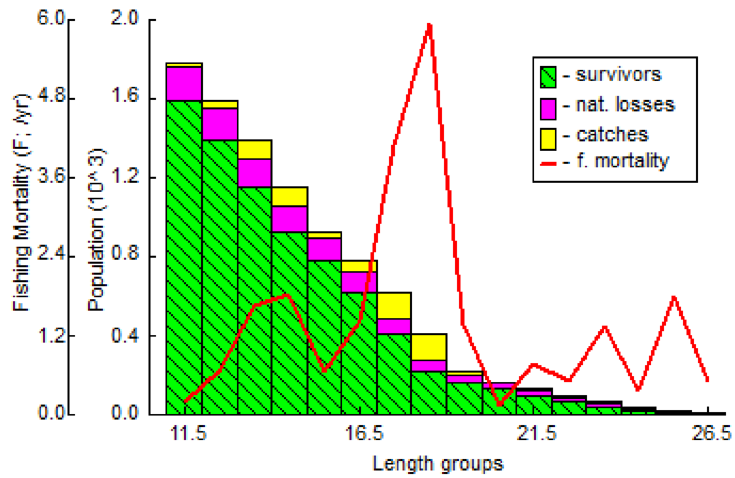

Figure 8: Virtual population analysis of *R. kanagurta* in the Marudu Bay, Sabah, Malaysia

Discussion

The estimated b value of *R. kanagurta* is 3.215 and it is lies between the values mentioned by Carlander (1977) and Ecoutin et al. (2005), which is significantly (*p<.05*) hifger than isometric value (3) at 5% level. Previous study on length-weight relationship *R. kanagurta* at Kuantan coastal waters of Malaysia showed that the b value was 2.905 (negative allometric growth) and this growth pattern might be influenced by environmental or habitat factors and availability of food (Rahman and Hafzath, 2012). According to Tesh (1971) length-weigh relationship of fish are affected by many factors including season, habitat, gonad maturity, sex, diet, health and preservation techniques. Based on Table 3, the asymptotic length, L_∞ value of *R. kanagurta* at Gulf of Suez was 30.76 cm (Mehanna, 2001) and 33.28 cm at the Tuticorin coast in India (Abdussamad et al., 2010) while in the present study the asymptotic length was estimated at 27.83 cm which is slightly lower than both researchers. On the other hand, the value of growth coefficient, K in the present study was 1.50 yr^{-1} while Mehanna (2001) and Abdussamad et al. (2010) reported them at 0.63 yr^{-1} and 1.63 yr^{-1}, respectively.

Table 3: Growth parameters (L_∞, and K) and exploitation level (E) of the *R. kanagurta* (combined sexes) from different locations

Location	L_∞ (cm)	K yr^{-1}	E	Source
Marudu Bay (Malaysia)	27.83 TL	1.50	0.45	Present study
Gulf of Suez (Egypt)	30.76 TL	0.63	-	Mehanna (2001)
Mangalore – Malpe Coast (India)	30.70 TL	1.80	0.66	Rohit and Gupta (2004)
Tuticorin coast (India)	33.28 TL	1.63	0.86	Abdussamad et al. (2010)

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In the present study, the total mortality for *R. kanagurta* in the Marudu Bay, Sabah was 4.44 yr^{-1} which is lower than the value of total mortality in Mangalore – Malpe coast (Rohit and Gupta, 2004) which was 7.63 yr^{-1}. For the natural mortality (M) and fishing mortality (F) in the present study, the values were 2.46 yr^{-1} and 1.98 yr^{-1}, respectively. Compared to results by Rohit and Gupta (2004), their natural mortality and fishing mortality were 2.60 yr^{-1}, 5.00 yr^{-1}, respectively. The exploitation level (E) in the present study was 0.45 (Table 3). Based on this value, the stock of *R. kanagurta* in the present study is below the optimum level of exploitation. This is according on the assumption that a stock is optimally exploited when fishing mortality (F) equals natural mortality (M), or E = (F/Z) = 0.5 (Gulland, 1965). The value of exploitation level for the present study was lower than the exploitation level in Mangalore – Malpe coast (Rohit and Gupta, 2004) and in Tuticorin coast (Abdussamad et al., 2010), which were 0.66 and 0.86, respectively (Table 3).

This study elucidated that the recruitment pattern of *R. kanagurta* is continuous with two major peaks throughout the year (Fig. 6). This study showed two major recruitment events per year indicating two cohorts were produced in a year. On the other hand, one recruitment peak per year for *R. kanagurta* is reported from the other location (Abdussamad et al., 2010). Biological characteristics and locality could possibly contribute to the difference in recruitment process. There is, however, no published report on recruitment of *R. kanagurta* in Malaysia so far.

Lower fishing mortality of *R. kanagurta* verses the natural mortality observed from the present study indicated the unbalance position in the stock. Exploitation level of *R. kanagurta* was slightly lower than the optimum level of exploitation. Two major recruitment peaks per year was observed in *R. kanagurta* in the study area. The present work offered the first basic information that can be useful in the stock assessment of *R. kanagurta* from Malaysia. This would be very useful to prevent the decline of fish populations and for its sustainable fishery management in Malaysia.

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