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Population structure of Indian mackerel, *Rastrelliger kanagurta* (Cuvier, 1816), from the Suez Bay, Gulf of Suez, Egypt

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Abstract
An investigation on Age, growth, and stock assessment of the Indian mackerel, *Rastrelliger kanagurta* (Cuvier, 1816) was studied "between" September 2012 to May 2013 from the Suez Bay. The length of the fish in samples ranged from 15.5cm to 32.5cm of TL. The common equation of length-weight relationship estimated for combined sexes was $W=0.0053*L^{3.2135}$. Von Bertalanffy growth parameters were estimated as L_{∞} = 33.79 cm, K = 0.428 year^{-1} and t_0 = -0.868 year. The growth performance index was estimated as 2.672. The annual total mortality (Z), natural mortality (M)were calculated as 1.917/year and 0.72/year respectively while Fishing mortality (1.197/year) was higher than the biological reference points (F_{opt} =0.60 and $F_{limt.}$ =0.80), additionally the exploitation rate (0.62) was higher than the exploitation rate ($E_{0.5}$ = 0.39) which maintain 50% of the stock biomass as spawning stock this results indicate that population of *Rastrelliger kanagurta* is overexploited in the Suez Bay ecosystem.

Keywords: Indian mackerel, *Rastrelliger kanagurta*, Age, Growth, Mortality, Suez Bay

1. Introduction
The Indian mackerel, *Rastrelliger kanagurta* (Cuvier, 1816), is a pelagic species with a wide range of distribution, inhabiting mainly the Indian Ocean and western part of the Pacific. It has special significance in the economy of the countries in the tropical region, where the species is considered an important source of inexpensive protein and is also commonly used as bait [24]. Due to the special importance of the species for the coasts of countries surrounding the Pacific Ocean the Red Sea, Gulf of Suez, Oman Sea, Arabian Gulf, Pakistan, India, Sri Lanka, Bangladesh, Myanmar, Thailand and Malaysia numerous researches were carried out on the biology and dynamics of *R. kanagurta* on varies coasts [2- 6, 17, 18, 20, 21, 25, 28, 29, 33, 37, 40, 42, 43, 52, 53, 56, 57, 62- 64, 68].

On the other side studies on the biology and stock assessment of Indian mackerel from Red sea and the Gulf of Suez are available [51]. Studied age, growth and mortality rates of *R. kanagurta* from Red Sea near Al-Ghardaqa; [59]. Investigated age, growth and mortality rates of *R. kanagurta* from the Gulf of Suez; [40]. Studied the population dynamics of the Indian mackerel in the Gulf of Suez.

The present work is the first to study the basic information on age, growth, mortality and yield per recruit of the *R. kanagurta* in the Suez Bay, This would be very useful to study the case of fish populations and for its sustainable fishery management in the northern part of the Gulf of Suez (Suez Bay).

2. Material and Methods
2.1 Study area
Suez Bay is a shallow extension of the Gulf of Suez, roughly elliptic in shape, with its major axis in NE SW direction from 29° 51N to 30° N. Average length along the minor axis of the bay is 18.8Km, while the mean depth 10 m., and its surface area is 77.13 Km^2 [41]. It is connected to Suez Canal by a dredged channel and to the Gulf of Suez though most of its southeastern side. City of Suez occupies their northern part of the bay. (Fig.1)

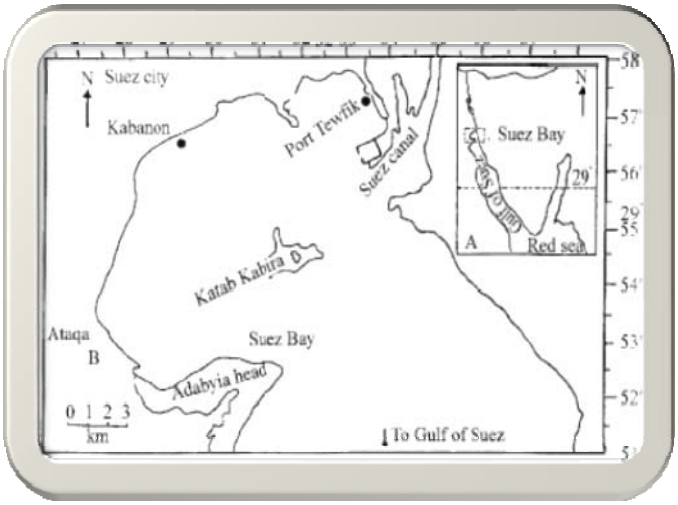

Fig 1: Map of Suez Bay coast**.**

2.2. Sample collection and analysis

Sample of *Rastrelliger kanagurta* were monthly collected from the commercial Purse sine operating in the Suez Bay landing in (EL-Salakhana small landing port) during the fishing season (2012/2013). Specimens were sorted by sex and measured for total length (cm.,) and weighed for total and gutted weight (g.,). To calculate length - weight relationship commonly used equation: $W = a\ L^b$ was applied, where W is the total weight (g), L is the total length (cm.,) and a & b are constants computed by [53].

Age and growth: The FISAT software [25] was used with the monthly length-frequency distributions for determination of age and growth rates by applied [14] method, while **L_∞ and k** were estimated by applying the methods of [22, 70, 11, 31]. While t_0 was estimated by undertaking linear regression between age (t) and in (Loo - Lt/L») where L_t is the length at age t.

The longevity (t_{max}) was obtained by the following equation [46] Pauly (1983): $t_{max} = t_0 + 3/k$ Where t_{max} is the approximate maximum age the fish of a given population would reach.

The growth performance index Ø was determined according to [46] as following:
$Ø = \log K + 2 * \log L_\infty$.

Mortality: The total mortality rate (Z) was determined according to [35] method. The natural mortality rate (M) was calculated by the mean of two methods: [32] method as: $M = 4.22 / t_{max}$, where t_{max} is the time required for a fish to reach 95% of the species L_∞, or the maximum age, and [36] using the formula: $M = (-\ln (0.01) / t_{max}$. The instantaneous rate of fishing mortality (F) was extracted as: $F = Z-M$.

The exploitation rate (E) was calculated as equal to the fraction of death caused by fishing. $E = F/Z$. [31]

The exploitation ratio (*U*) was calculated by the equation as, $U = F/Z\ (1-e^{-z})$.

Length at first capture (L_c) was estimated according to [10]:
$L_c = \bar{L} - K\ (L_\infty - \bar{L}) / Z$, where $\bar{L}$ is the mean length of the catch, K and L∞ are the growth parameters of von Bertalanffy equation and Z is the rate of total mortality. The corresponding age at first capture (T_c) was calculated as: $T_c = - 1/K\ ln\ (1- L_c / L_\infty) + t_o$.

The length that generates optimum yield per recruit (Lopt) was estimated by [13] (Beverton, 1992) based on [11].

$L_{opt} = L_{inf} * (3 / (3 + M/K))$ (Beverton 1992).
The length at first sexual maturity (Lm) was estimated by [22] empirical equations.

Relative yield per recruit Y'/R and relative biomass per recruit B'/R were calculated using the model of [12] as modified by [49] using FISAT software.
as $Y`/R = EUM/K\ [1 - (3U/1+m) + (3U2/1+2m) – (U3/1+3m)]$ *where,* $U = 1- (Lc / L\infty)$, $m = (1-E)/ (M/K) = (K/Z)$: M is the natural mortality, K is the body growth coefficient and E is the exploitation rate and the relative biomass per recruit $(B'/R) = (Y'/R)/F$. The exploitation rate producing maximum yield (*Emax*), the exploitation rate at which the marginal increase of Y'/R is 10% of its virgin stock (*E0.1*) and the exploitation rate which the stock is reduced to 50% of its unexploited biomass (*E0.5*) were estimated. Also, the yield contours were plotted to assess yields on changes in E and $Lc / L\infty$.

Resource status was assessed by comparing estimates of the fishing mortality rate with target (F_{opt}t) and limit (F_{limit}) biological reference points (BRP) which were defined as: F_{opt}=0.5M and F_{limit}=2/3M [44]

3. Results and discussion

3.1. Fishery

The Indian mackerel *Rastrelliger kanagurta* (Cuvier) is a pelagic shoaling fish, coated by purse seine method in Suez Bay. A purse seine is a type of ancient fishing equipment that has been used for a longtime in coastal fisheries throughout the world and extensively used in the Mediterranean Sea. Purse seine is a fishing method capable of harvesting large quantities of surface-schooling pelagic fish by surrounding the school with an encircling net. In Egypt, the first large-scale use of the purse seine was in the Suez Bay north of the Red Sea fishery during the 1960s and after a few years on the Egyptian Mediterranean coast. It is commonly used on dark nights with artificial lights for fish attraction carried on two or three small boats. One mother boat is used to release and collect the net [5]. The estimated landings of Indian mackerel from the Suez Bay, EL-Salakhana site for the period 2000 - 2014 are given in Fig.2. The catches ranged from 700 kg, in 2009/2010 to 10160 kg, in 2013/2014. And the annual average catches of Indian mackerel at 4655.7 kg.

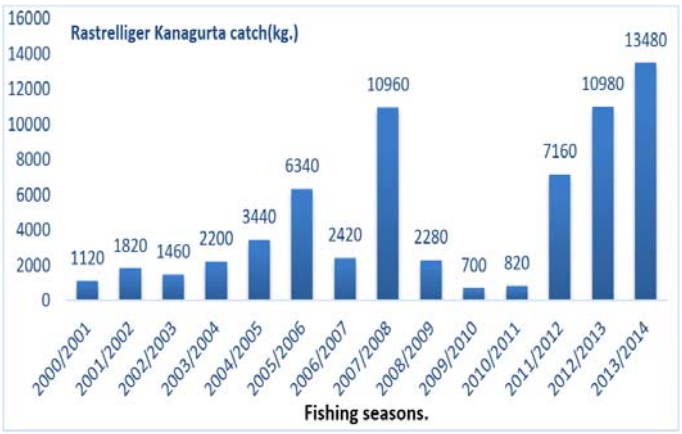

Fig 2: Catches of *R. kanagurta* from Suez Bay (El Salakhana) coast**.**

3.2. Length-weight relationship

A total of 254 specimen 119 males, 72 females and 62 unknown collected from Suez Bay at El Salakhana site had length ranged from15.5 to 32.5cm., with an average of 25.70±4.13cm., while total weight varied from 29 to 339 gm., with mean of 179.2±85.78 gm. length and weight relationship for males and females were analyzed separately but give no significant differences between the slop. Hence, the equation for sex's pooled data would be ideal for the Indian mackerel in Suez Bay. The estimated length-weight relationship in *R. kanagurta* Fig. 3 was, $W = 0.0053x^{3.2135}$ ($R^2 = 0.98$). The calculated growth coefficient *b* was 3.214 and the constant *(a)* was 0.0053. The length weight relationship of *R. kanagurta* indicated positive allometric growth in the Suez Bay. The length-weight relationships of *R. kanagurta* estimated from different regions indicated the 'b' values ranging from 3.010 to 3.475 [1, 2, 4, 20, 28, 34, 36, 39, 40, 42, 43, 49, 51, 56, 57, 58, 64, 66, and 69]. Table (1)

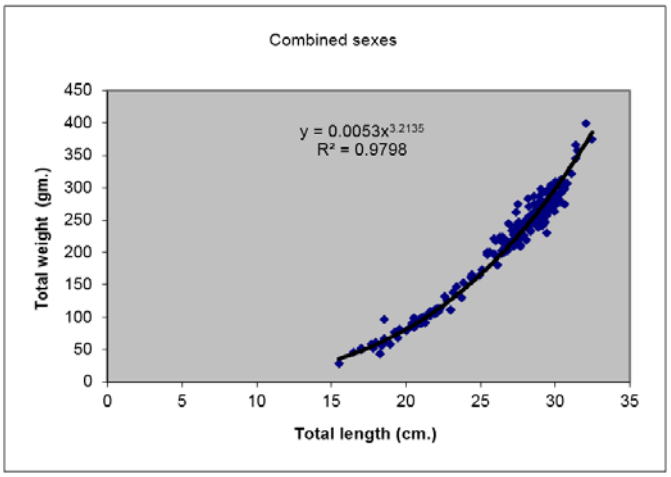

Fig 3: Length-weight relationship of *Rastrelliger Kanagurta* caught by purse seines in the Suez Bay (2012/2013).

Table 1: Length-weight relationships of *Rastrelliger Kanagurta* in different regions.

Regions	a	b	Authors
Egypt:			
Suez Bay: Males Females Combined sexes	 0.005 0.004 0.005	 3.210 3.313 3.214	present study
Red Sea.	0.004	3.26	Rafail 1972 [51]
Gulf of Suez			Sanders *et al.*, 1984 [59]
Gulf of Suez:			Mehanna 2001[40].
Males	0.005	3.198	
Females	0.006	3.168	
India:			
India	0.000029	3.3087	Jones and Silas 1962. [34]
India			
India	31.3	0.64	Sekharan *et al*., 1969. [62]
India	0.000002164	3.2874	Luther.1973. [39]
India	31.6	0.6	Banerji&Krishnan, 1973. [8]
India	31.3	0.64	Pauly. 1978. [45]
India	0.0000013848	3.3805	Gopakumar *et al*. 1991.[28]
India	0.000000795	3.475	Noble *et al*. 1992. [43]
India	0.000001385	3.3805	Rohit *et al*. 1998. [57]
Mangalore – Malpe Coast (India)	0.004457	3.29	Rohit and Gupta 2004. [56]
India	0.00000121	3.340179	Abdussamad *et al*. 2006 [2]
Other regions:			
Indonesia	0.0039	3.19	Tampubolon 1988 [66]
Saudi Arabia	0.0040	3.33	Sanders and Morgan 1989. [58]
Yemen	0.0170	3.010	Edwards and Shaher 1991 [20].
South Africa	0.0064	3.170	Torres, 1991. [68]
Philippines	38	0.8	Guanco, 1991.[29]
Indonesia	0.0061	3.174	Pauly *et al*. 1996. [49]
Pakistan	0.00544	3.207	Moazzam *et al*. 2005. [42]
Yemen AL-HODEIDAH REGION	0.0083	3.096	Al-Mahdawi Gh. 2010. [4]
Marudu Bay (Malaysia)	0.006	3.215	Amin 2014. [6]
Sohar coast of Oman	0.0035	3.388	Jayabalan. N. *et al.*, 2014 [33].

3.3. Age and growth

Length frequency distribution used for age determination of *Rastrelliger Kanagurta* caught by purse seines in the Suez Bay (2012/2013). Age group with mean lengths of 17.29, 22.38, 27.20 and 30.50 cm for age groups I, II, III and IV respectively. (Fig. 4) (Table. 2.)from the table it is clear that; The mean estimated lengths at different age groups indicated, The growth rate in length gradually decreases with the increase in age, where the highest value in the first year of life while, the lowest value was recorded in the fourth year of life. Similar reported result was estimated by [27, 51, 39, 40, 4].

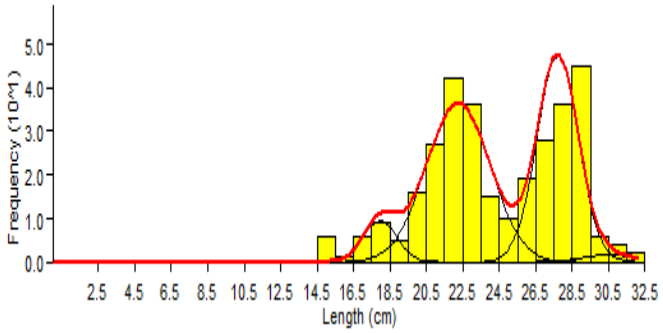

Fig 4: Age determination by the Bhattacharya method.

Table 2: Mean length and percentage at age estimated for *Rastrelliger Kanagurta* caught by purse seines in the Suez Bay (2012/2013 from length frequency distribution [14].

			Bhattacharya method.		
Age	**Mean Length**	**Population**	**SD**	**S.1**	**%**
I	17.29	23	1.000	n.a	9.05
III	22.38	131	1.180	4.02	51.57
III	27.20	86	1.240	4.00	35.10
IV	30.50	14	1.290	2.62	5.51

Where SD = standard deviation
S.I. = separation index

3.4. Age composition

Fig.5. Show that the percentage occurrence of these groups illustrated that Age group II constituted the greater part of the catch with 51.57% of the aged individuals. This means that *R. kanagurta* in the Suez Bay becomes fully recruited to the fishery at an age of two years. This result is in a good agreement with the finding of [4] in Yemeni coast of Red Sea.

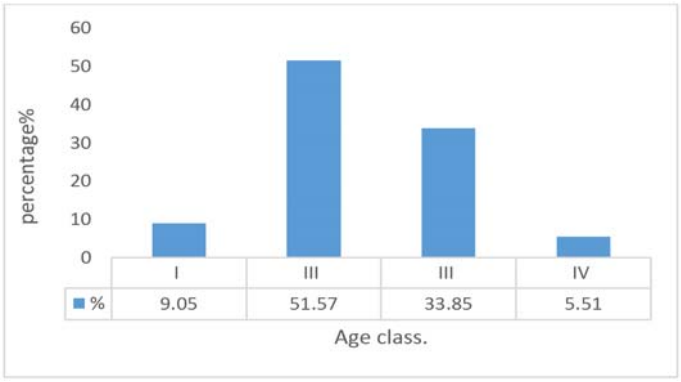

Fig 5: Age composition of *Rastrelliger Kanagurta* caught by purse seines in the Suez Bay (2012/2013)

3.5. Theoretical Growth

The growth parameters of the von Bertalanffy growth model were estimated by applying three methods: [22, 70, 16, 31]. Those results and the results by previous studies in other regions were summarized in Table 3. It is clear that the present results more or less similar to those revealed from the previous studies. The differences in growth parameters were due to age, sex, maturity and sampling period for the same species**.**

Growth performance index

The value of growth performance index (Φ') of *R. kanagurta* was calculated as 2.69 the present value was found to be in the range of those recorded for the same species in other localities. Table 3.

Table 3: Summary of the estimated growth parameters of *Rastrelliger Kanagurta* indifferent regions.

Regions	**L_∞(cm)**	**K year^{-1}**	**t_o**	**ø**	**Source**
Egypt:					
Suez Bay	33.79	0.428	-0.868	2.672	present study
Red Sea.	42	0.26	-0.95	2.71	Rafail 1972 [51]
Gulf of Suez	40	0.23		2.57	Sanders *et al.*,(1984 [59]
Gulf of Suez:					Mehanna 2001 [40]
Males	29.48	0.66	-0.055	2.76	
Females	32.04	0.6	-0.118	2.79	
Sexes combined	32.15	0.57	-0.053	2.77	
India:					
India	31.6	0.6			Seshappa.1958 [60]
India	31.3	0.64			Sekharan *et al.*,1969 [62]
India	39	0.74			Luther.1973 [38]
India	31.6	0.6			Banerji&Krishnan,1973 [8]
India	31.3	0.64	-0.06		Pauly.1978 [44]
Mangalore – Malpe Coast (India)	30.7	1.8			Rohit and Gupta (2004) [56]
Tuticorin coast (India)	33.28	1.63			Abdussamad *et al.* 2010 [3]
Other regions:					
Yemen AL-HODEIDAH REGION	32.5	0.58	-0.18	2.79	Al-Mahdawi Gh.(2010) [4]
Marudu Bay (Malaysia)	27.83	1.5			Amin(2014) [6]
Seychelles	31.7	0.64			Lablache *et al.*,1988 [38]
South Africa	30.3	0.72			Torres,1991 [68]
Philippines	38	0.8			Guanco,1991 [29]
Yemen	32.3FL.	0.67	-0.69		Edward&Shaher,1991 [20]
Sohar coast of Oman	34	0.86	-0.06		Jayabalan.N.*et al.*,2014 [33]
Marudu Bay (Malaysia)	27.83	1.5			Amin(2014) [6]

Length at first sexual maturity Lm

The length and age at first sexual maturity are very important parameter in fisheries research to assess the optimum age of first capture of a species. This study indicates the *R. kanagurta* attain at first sexual maturity at 20.42cm. This value is conforming to an age 1.120 year [50]. Observed that the Indian mackerel matured for the first time when it measured 21.0 – 22.0 cm which is in agreement with the present observation.

Similar reported result was reported by [54] have indicated that Indian mackerel below 20.0 cm are immature. [15] reported that the first maturity for male is at 19.8 cm and for female at 20.6 cm., [18] defines the male or female specimens were firstly matured at 19.55 cm or 20.71 cm, respectively.

Length at first capture Lc

The length at first capture (the length at which 50% of the fish at that size are vulnerable to capture) was estimated as Lc =19.37cm, this value is corresponding to an age of 1.121 year.

Mortality and Exploitation Rates

In the present study by applying the method of [34] The total mortality coefficient *Z* was estimated as 1.917 year^{-1} Fig. 6,while the natural mortality coefficient *M* was calculated by the mean of two different methods and the obtained value was 0.72 year-1. Then, the fishing mortality coefficient F was estimated at 1.197 year-1 was much greater than both the target (F_{opt} = 0.599/yr) and limit (F_{limit} = 0.798/yr) biological reference points. On the other hand by applied F and Z values, the estimated exploitation ratio (E) was found to be 0.624.

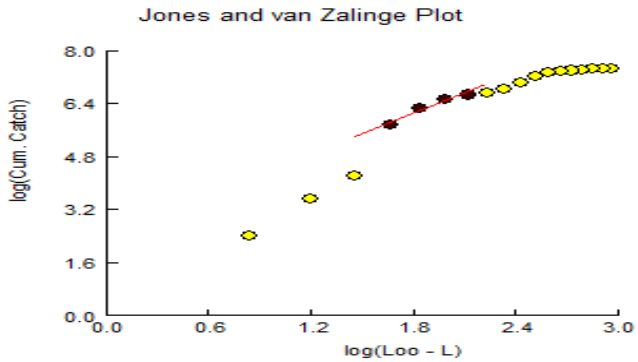

Fig 6: Z- Estimation of *Rastrelliger kanagurta* from Gulf of Suez, Suez Bay.

Relative Yield per Recruit Y'/R

The estimated relative yield per recruit of *R. kanagurta* in the Suez bay is represented graphically in Fig. 7. The results indicate that, the present level of exploitation rate (E = 0.62) was higher than the exploitation rate (E0.5 = 0.39) which maintain 50% of the stock biomass as spawning stock. It could be concluded that the *R. kanagurta* stock in the Suez bay is in a situation of overexploitation and for the management purpose the current exploitation rate should be reduced to the level of E0.5. To insure that the present level of exploitation rate should be reduced from 0.62 to 0.39 (37.1%).

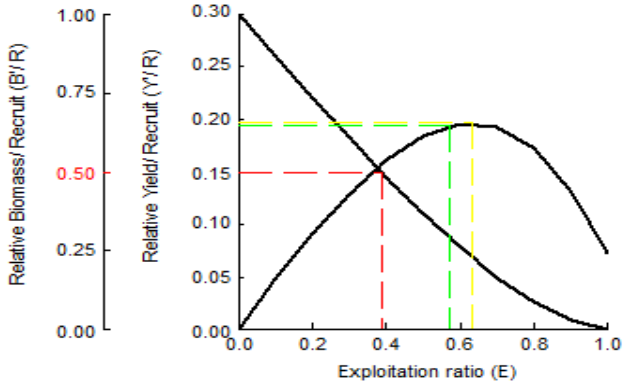

Fig 7: Relative yield per recruit of *Rastrelliger kanagurta* from Suez Bay.

Optimum length

The fishery would reach the maximum possible yield if it were to catch only fish of the optimum size [13]. The optimum length (L_{opt}) for a given stock is defined as the length class that generates highest yield, where the number of survivor multiplied with their average weight reaching a maximum, was calculated according to the relationship between L_{opt} and the von Bertalanffy growth function. The derived estimate of this optimum length for *R. kanagurta* was 21.65. cm. in the present work the length at first capture (Lc = 19.36 cm) is smaller than the length at first maturity (Lm=20.42cm.) and the optimum length(Lopt =21.65), the length at first capture for this population should be increased to obtain the maximum possible yield and to maintain the sustainability of the specie.

4. Conclusion

Suez Bay represented important nursery ground for the most common species in the Gulf of Suez and the Red Sea. *R. kanagurta* in Suez Bay appear to be over exploited as the current F is higher than the defined values of reference points F_{opt} and F_{lim}. So, It must be reducing of fishing pressure especially fishing on the nursery and spawning grounds. In addition the current of exploitation rate should be reduced to the level of E0.5, besides that the length at first capture for this population should be increased to preserve the sustainability of this species, also The longevity of 6.2 years was estimated, however the maximum number of fishes caught was recorded at age group two this indicates they coughed before they grow large enough, and this cause growth overfishing.

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