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Contributed Paper

Population Dynamics of *Polynemus paradiseus* from Estuarine Set Bag Net Fishery of Bangladesh

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ABSTRACT

Population parameters of *Polynemus paradiseus* were estimated with length-frequency data collected from Estuarine Set Bag Net Fishery of Chittagong and Cox's Bazar region in Bangladesh during the period from January 2005 to December 2005. FiSAT software was used to estimate the parameters. The asymptotic total length (L_∞) and growth constant (K) were estimated to be 20.48cm and 0.48 y^{-1} respectively. The instantaneous rate of natural mortality (M), fishing mortality (F) and total mortality (Z) were estimated to be as 1.21 y^{-1}, 3.17 y^{-1} and 4.38 y^{-1} respectively. The value of exploitation rate (E) was found to be 0.72 which clearly pointed toward over-fishing condition ($E > 0.50$) for *Polynemus paradiseus* in the ESBN fishery of Bangladesh. The recruitment pattern of the species was found continuous all round the year with two peaks one in the months of March-April and another in the months of August-September. The length-weight relationship was found to be $W = 0.0087L^{2.7398}$ signifying isometric growth for this species. Virtual population analysis estimated that the maximum numbers of *Polynemus paradiseus* are caught between 3.5cm to 11.5cm with maximum F value (2.09 y^{-1}) in the mid length of 8.5cm. Relative yield per recruit (Y'/R) and biomass per recruit (B'/R) suggested that the fishing mortality should be reduced to 1.559 y^{-1} to obtain maximum sustainable exploitation rate ($E_{max} = 0.356$) for the species *P. paradiseus* in ESBN fishery of Bangladesh.

Keywords: asymptotic length, growth coefficient, mortality, over-fishing, virtual population analysis, maximum sustainable exploitation rate.

1. INTRODUCTION

Fisheries biologists contribute to fisheries science in two main areas – firstly, by studying the basic biology and distribution of resource species, and secondly, by studying the population dynamics of species [1]. In fish population dynamics study, the most important task is to estimate population parameters i.e. growth, recruitment and mortality of a specific fish or a group of fish species. However, the system is dynamic and values of these parameters fluctuate between different stocks and places of the same species. Estimation of this parameters leads towards the prediction of fish stock assessment from which a clear concept about the present status of a specific fishery can be ascertained for management purpose.

The asymptotic length (L_∞) is the theoretical maximum length that the species would reach if it lived indefinitely and growth coefficient (K) is a measure of the rate at which maximum size is attained [1]. In fisheries science, the most useful way to express the decay of an age group of fish through time is by means of exponential rates from which the "instantaneous rate" of total mortality can be calculated using the *length converted catch curve* [2]. Probability of capture gives a clear idea about the estimate of the real size of fish in the fishing area which is being caught by the specific gear. At the same time, it is an important tool for fisheries managers who, by regulating the minimum mesh size of a fishing fleet, can more or less conclude what should be the minimum size of the target species of a fishery. Growth in terms of length and weight is a permanent process with rise and fall in fishery due to seasonal variations, multiple spawning and variation in food composition. Length and weight of fishes bear a specific relationship if there is no change in form and specific gravity throughout life and from this relationship the physical well being of a fish can be ascertained for a given body of water at a given time [3]. According to Medawar's first law of growth [4], animal always grow bigger and it is true for fishes when growth is measured in terms of length [5]. According to LeCren [6] the objectives of length-weight relationship is to (1) prove measurement of variation from expected weight for length of individual fish as an indication of fatness, general wellbeing, gonad development etc., and (2) give indications of taxonomic differences and events in the life history of fish when growth rate for weight are converted to logarithmic forms. Virtual population analysis use the number of fish caught during fishing operation to estimate the historic fishing mortality and stock number in a cohort (group) of fish [7]. It is used to reconstruct fish population structure by age or length group. The relative yield-per-recruit and biomass-per recruit allow prediction of long term yield under different fishing regimes [8]. The model is commonly used to suggest the changes in yield which would result from changing fishing effort, and therefore fishing mortality, and delaying the length at first capture [1].

Polynemus paradiseus is widely distributed in the Indo-pacific Ocean including the Bay of Bengal [9 – 11]. It has also been reported from Peninsular Malaysia, Philippines and Vietnam [12, 13]. In Bangladesh, it is one of the commercial fish species, specially in the coastal regions and one of the major fish species in the Estuarine Set Bag Net (ESBN) fishery of Bangladesh [14]. About 0.23 to 6.28% of the total catch (fresh wet weight) of the ESBN is contributed by this species [15]. In the coastal region of Bangladesh it is available almost all round the year. This fish is taken as fresh as well as in dried condition. Due to high demand of this fish [14] and the destructive nature of the ESBN [16] it is necessary to evaluate the population parameters of this fish from time to time to ensure the proper management of this fishery. Hence, the present study was designed to provide a clear picture of the population dynamics of the species *P. paradiseus* from the ESBN fishery of Bangladesh.

2. MATERIALS AND METHODS

2.1 Collection of Data

During the period January 2005 to December 2005 the fish *P. paradiseus* was collected from four coastal fish landing centers of the South-Eastern part of Bangladesh. Two of the landing centers (Kumira and Kattoli) were situated in Chittagong district while the other two (Moheskhali and Charpara) were situated in Cox's Bazar district (Figure 1) as around 52% of the total ESBN catch of Bangladesh is contributed from these regions [14]. In every month, consecutive five days ahead to the full moon, fishes were collected directly from the Estuarine Set Bag Net. At least 250 numbers of individual fish species per month were collected [17] randomly from the nets and their total length and corresponding body weight were measured to the nearest 0.1cm and 0.1g respectively.

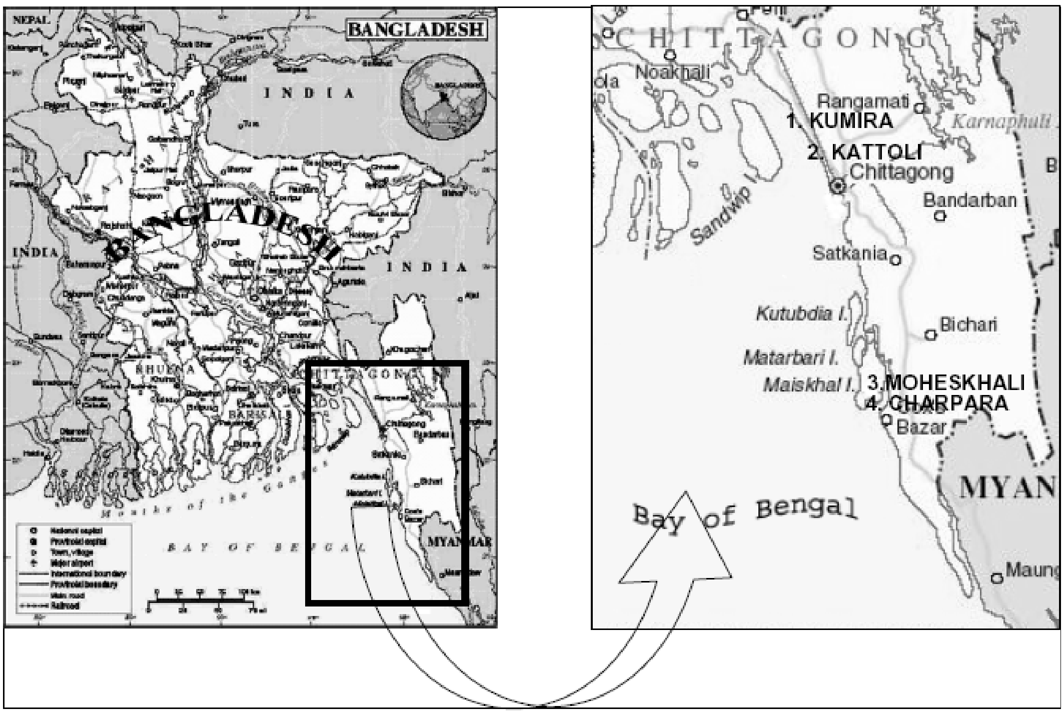

Figure 1. Study area of the present investigation.

2.2 Data Analysis

2.2.1 Estimation of Asymptotic Length (L_∞) and Growth Coefficient (K)

Month-wise Length frequency distribution data were used to estimate the total asymptotic length (L_∞ cm) and growth coefficient (K year^{-1}) of the Von Bertalanffy growth equation [18, 19]. The ELEFAN I and ELEFAN II routines incorporated in FiSAT software [8] were used to determine L_∞ and K value following the Powell–Wetherall method [20]. This method was used to provide an initial estimate of L_∞. This initial estimate of L_∞ was then used as seed value to determine the value of K [21]. Minor adjustments to L_∞ and K were made to maximize the "goodness of fit" criterion built into ELEFAN I [22]. This led to a preliminary estimate of L_∞ and K that were used to obtain "probabilities of capture" by length class using the routine in FiSAT. These "probabilities of capture" was used to correct the length frequency distribution data to account for incomplete selection and recruitment and the final estimates of L_∞ and K were obtained using these corrected length distribution data through ELEFAN I [21].

2.2.2 Mortality Estimation

Following the ELEFAN II routines in FiSAT [8], the total mortality [19, 23] coefficient, $Z(y^{-1})$ was estimated using the length-converted catch curve by means of the final estimates L_∞ of K and and the length frequency distribution data for the species *P. paradiseus*.

The rate of natural mortality $M(y^{-1})$ for each species was estimated using Pauly's empirical equation [24]

$$Log_{10}M=-0.0066-0.279Log_{10}L_\infty+0.06543Log_{10}K+.04634Log_{10}T$$

Here, T was taken as 27^{o}C [25].

Fishing mortality rate F (y^{-1}), was obtained by subtracting M from Z [21], i.e. $F = Z - M$

The exploitation ratio, E, was calculated by the following formula [23, 26] $E = F/(F+M)$.

2.2.3 Probability of Capture

Probability of capture, calculated from the length-converted catch curve routine, was used to estimate the final values of L_{25}, L_{50} and L_{75} (i.e. lengths at which 25%, 50% and 75% of the fish will be vulnerable to the gear) [27].

2.2.4 Recruitment Pattern

Recruitment pattern was obtained by the backward projection, of the frequencies onto the time axis of a time-series of samples along a trajectory defined by the Von Bertalanffy growth equation; this routine reconstructs the recruitment pulses from a time series of length-frequency data to determine the number of pulses per year and the relative strength of each pulse [28].

2.2.5 Length-weight Relationship

The most widely used formula for the expression of the Length-weight relationship $W = aL^b$ [6, 29] was followed for the present analysis; where 'a' is a constant, 'b' is an exponent, W is the weight and L is the corresponding total length of the weight. The exponential form of this formula may be converted in the natural logarithmic form a follows:

$$lnW = a + b\,lnL$$

The value of 'a' and 'b' was calculated by using the following mathematical relationship

$$ln(a) = \frac{\Sigma lnW \Sigma(lnL)^2 - \Sigma lnL \Sigma(lnL\,lnW)}{N\Sigma(lnL)^2 - (\Sigma lnL)^2}$$ and,

$$b = \frac{\Sigma lnW - N\,ln(a)}{\Sigma lnL}$$ [6, 30 – 31], where

N = number of classes used in the calculation.

2.2.6 Virtual Population Analysis

Terminal population (N_t) were estimated from $N_t = C_t(M+F_t)/F_t$ where, C_t is the terminal catch and F_t is the terminal Fishing Mortality and M is the Natural Mortality. Starting from N_t, successive values of F were estimated, by iteratively solving

$$C_i = N_i + \Delta t(F_i/Z_i)(exp(Z_i\Delta t_i)-1)$$

[28]

where, C_i = catch (in number) for a population during a unit time period i

$$\Delta t_i = (t_{i+1} - t_i)$$, and

$$t_i = [t_0 - (1/K)ln(1-(L_i/L_\infty))]$$

The population sizes (N_i) was computed from $N_i = N_{i+\Delta t_i}\,exp(Z_i)$.

The last two equations were used alternatively, until the population sizes and fishing mortality for all length groups have been computed [27, 32].

2.2.7 Relative Yield-per-recruit and Biomass-per-recruit

Relative yield-per-recruit (Y'/R) was computed using the following formula [8, 23]

$$Y'/R = EU^m\left(1 - \frac{3U}{(1+m)} + \frac{3U^2}{(1+2m)} - \frac{U^3}{(1+3m)}\right)$$

where, $U = 1-(L_c/L_\infty)$, $m = (1-E)/(M/K) = K/Z$, $L_c \cong$ means length of fish at first capture i.e. length at which 50 percent of the fish are retained by the gear (L_{50}) and $E = F/Z$.

Relative biomass-per-recruit (B'/R) was estimated from the relationship $B'/R = (Y'/R)/F$ [11].

The value of E_{max}, $E_{0.1}$ and $E_{0.5}$ were estimated by using the first derivative of this function, where, E_{max} maximum sustainable exploitation rate,

$E_{0.1}$ = exploitation rate at which the marginal increase of relative yield-per-recruit is $1/10^{th}$ and

$E_{0.5}$ = value of E under which the stock has been reduced to 50% of its unexploited biomass.

3. Results and Discussion

3.1 Asymptotic Length (L_∞) and Growth Coefficient (K)

The minimum and maximum total lengths varied between 1.20cm and 20.00 cm and those of weight between 0.37g and 33.56g. These results do not agree with the results of Nabi *et al.* [33] where the maximum length was found to be 22.50cm and weight was fond to be 61.65g for the same species. This might be due to collection of the present samples only from the ESBN where merely juveniles are susceptible. The maximum total length of *P. paradiseus* from the Western Indian Ocean was reported to be 23.00cm [34] which also disagrees with the present investigation. The value of asymptotic length (L_∞) and the growth parameter (K) estimated by the ELEFAN I were found to be 20.48cm and 0.48 y^{-1} (Figure 2) respectively which are slightly less than the result 21.6cm and 0.52 respectively of Islam *et al.* [14]. This points towards that the maximum length of *Polynemus paradiseus* is decreasing over time.

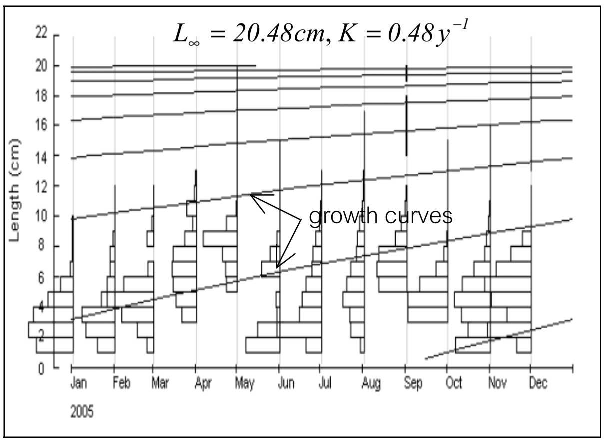

Figure 2. Length-frequency distribution of *P. paradiseus* in different months with superimposed growth curves as obtained from K-scan of FiSAT.

3.2 Mortality and Exploitation Rate

The length converted catch curve of *Polynemus paradiseus* was shown in Figure 3. The values for instantaneous total mortality co-efficient (Z), natural mortality co-efficient (M) and fishing mortality co-efficient (F) in the present investigation were found to be 4.38 y^{-1}, 1.21 y^{-1} and 3.17 y^{-1} respectively which disagree with the results of Islam *et al.* [14]. However, the exploitation rate (E) of the present investigation (0.72) roughly agrees with the result of Islam *et al.* [14] where the exploitation rate were found to be 0.79. As the exploitation rate was found higher then the optimum fishing level (0.5) then it can be concluded that high fishing pressure is prevailing in the ESBN fishery for this species.

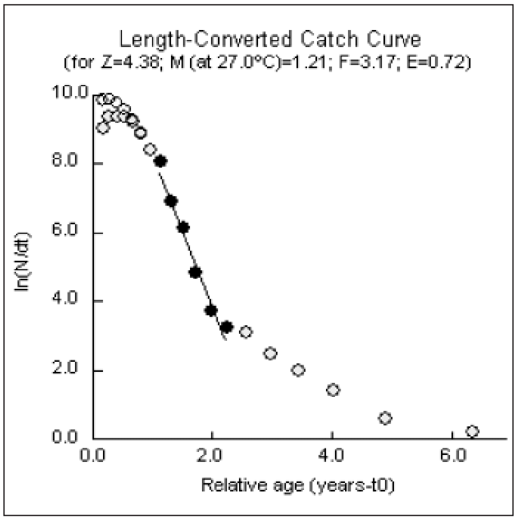

Figure 3. Length-converted catch curve for the species *P. paradiseus* that was used for estimating different mortalities and exploitation rate.

3.3 Probability of Capture

Figure 4 showed that the estimated length sizes for 25 % (L_{25}), 50 % (L_{50}) and 75 % (L_{75}) probabilities of capture would be 0.30cm, 1.11cm and 1.90cm respectively for *Polynemus paradiseus* indicating high catching probability of the juveniles to ESBN.

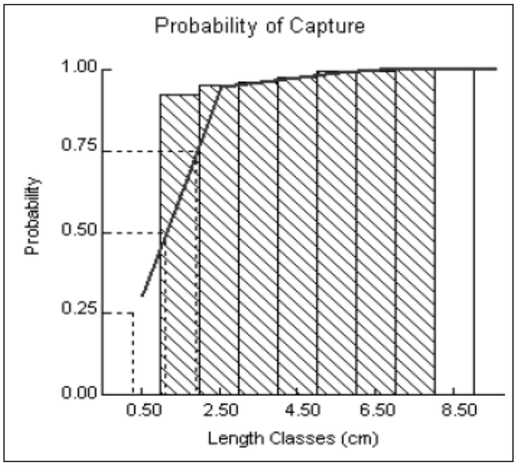

Figure 4. Probability of capture.

3.4 Recruitment Pattern

Two recruitment peaks were found in the present investigation (Figure 5), one in March-April and another in August-September with the presence of continuous recruitment in almost every month in the ESBN fishery of Bangladesh for *Polynemus paradiseus*. This agrees with the results of Kader and Nabi [35] where a prolonged spawning period was observed for *P. paradiseus* from the month of March to October. Islam *et al.* [14] also commented about the continuous recruitment pattern for ESBN fishes of Bangladesh.

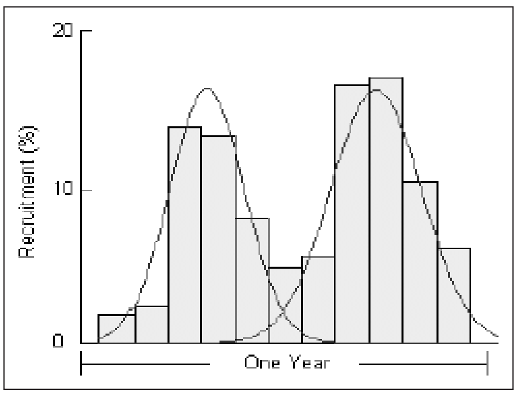

Figure 5. Recruitment patter of *P. paradiseus* for the investigated period.

3.5 Length-Weight Relationship

The minimum and maximum total lengths varied between 1.20cm and 20.00cm and those of weight between 0.37g and 33.56g. The exponential form of the equation was found to be $W = 0.0087L^{2.7398}$. Hile [30] proposed that the value of "b" for an ideal fish range between 2.5 and 4.0. In contrast, Ricker [36] recommended that the value of b should be exactly '3' when the growth is isometric. This cube law relationship is hardly expected as most of the species do changes their shape [30] and these changes is due to sex, maturity, seasons and even the time of day because of stomach fullness [37]. Since, the value of 'b' (2.74) in the present investigation is very close to '3' it can be concluded that isometric growth is expected in the fish *Polynemus paradiseus*. However, this isometric growth pattern do not agree with the result of Nabi *et al.* [33] where the values of 'b' was 3.3896 and 3.5115 for male and female respectively which is higher then the present values (2.74). This may be due to dominance of juveniles in the ESBN fishing. The coefficient of correlation (r=0.8998) between total length and body weight was found highly significant at 5% level of significance (Figure 6) which agrees with the result of Nabi *et al.* [33].

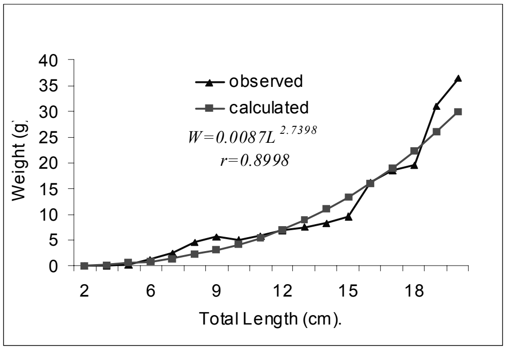

Figure 6. Length-weight relationship of the species *P. paradiseus* (unsexed).

3.6 Virtual Population Analysis

The F-at-length array showed (Figure 7, Table 1) that the maximum fishing mortality is occurring in the length between 3.5cm to 10.5cm with a maximum value in the length of 8.5cm again indicating high fishing mortality in the juvenile *Polynemus paradiseus* due to ESBN fishing operation. The total steady state biomass was found to be 11196.69 tones. The total population, catch (in number), fishing mortality and steady-state biomass (tones) per length class has been presented in the Table 1.

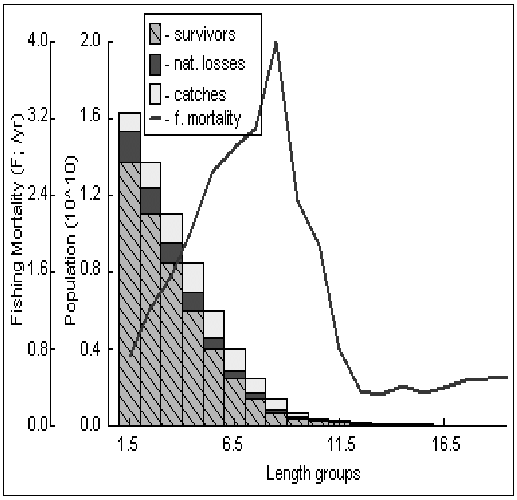

Figure 7. Virtual population analysis.

3.7 Relative Yield-per-recruit and Biomass-per-recruit

The Y'/R and B'/R curve (Figure 8) for different exploitation Rates (E_i) produced a $E_{\max}$ value from which $F_{\max}$ was calculated and in the case of *P. paradiseus* the value of $E_{\max}$ and corresponding $F_{\max}$ value were found to be 0.356 and 1.559 y^{-1} respectively. The $E_{0.1}$ and $E_{0.5}$ values were found to be 0.255 and 0.234 respectively.

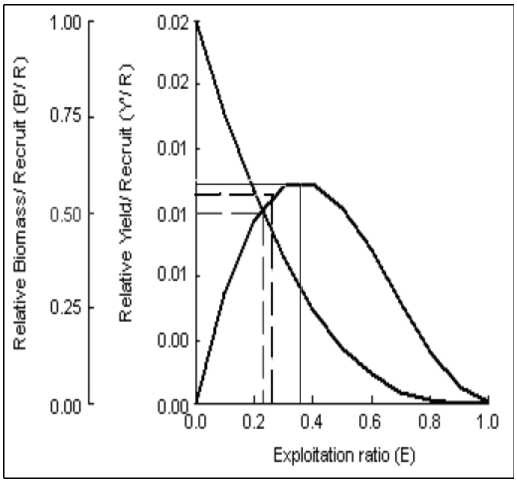

Figure 8. Relative yield-per-recruit and biomass-per-recruit for the species *P. paradiseus.*

4. Conclusion

In The present investigation the maximum total length (L), asymptotic length (L_∞) and growth coefficient (K) of the fish *Polynemus paradiseus* was found less then the previous studies. This is because of the overexploitation (F= 3.17 y^{-1}; $E = 0.72$) of this species in the Bay of Bengal due to ESBN fishing. Relative yield per recruit (Y'/R) and biomass per recruit (B'/R) suggested that the fishing mortality should be reduces to 1.559 y^{-1} to obtain maximum sustainable exploitation rate ($E_{\max} = 0.356$) for this species. Hence, to reduce the fishing mortality necessary measures should be developed for the sustainable management of this fishery.

Table 1. Virtual population analysis showing the total population, catch (in number), fishing mortality and steady-state biomass (tones) per length class for *P. paradiseus.*

Mid-Length	Catch (in numbers)	Population (N)	Fishing mortality (F)	Steady-state Biomass (tones)
1.5	943000000	20062492672	0.49	55.15
2.5	1368000000	16817656832	0.83	182.93
3.5	1463000064	13463117824	1.07	375.48
4.5	1528000000	10353370112	1.41	588.69
5.5	1424999936	7520279552	1.75	761.18
6.5	1064000000	5118349312	1.83	856.94
7.5	741000000	3357153024	1.84	877.41
8.5	556000000	2133269376	2.09	816.99
9.5	190000000	1257917824	1.05	753.77
10.5	100000000	850556480	0.74	739.22
11.5	30000000	588450432	0.28	741.99
12.5	11000000	431594976	0.13	760.62
13.5	8000000	317089408	0.11	763.72
14.5	8000000	224904624	0.14	733.03
15.5	5000000	150459936	0.12	669.08
16.5	4000000	94934560	0.13	575.75
17.5	3000000	54297940	0.15	453.54
18.5	2000000	26732602	0.17	312.41
19.5	3000000	10200001	0.50	178.79
Total Steady state biomass				**11196.69**

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