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Growth and Exploitation Rate of the Bombay Duck (*Harpodon Nehereus* Hamilton, 1822) (Fish: Synodontidae) in Tarakan Island Waters, Indonesia

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Abstract

The Bombay duck (*Harpodon nehereus*) is an economically important fish inhabiting Tarakan waters of North Kalimantan Province. Unless an appropriate management performed, an ever increasing in exploitation of this synodontid species will threat its population sustainability. A research was conducted from March 2013 to February 2014 in Tarakan waters aiming to investigate on growth and exploitation rate of the Bombay duck. Three sampling sites were determined for the purpose of sample collection. Fish was collected by a trawl of 1: 2: 2 cm in mesh size, towed for 30 minutes at each sub-station. On board, approximately 50 individual fishes of various size were randomly collected. In total, 1051 fishes were collected consisting of 544 males and 507 females. Data of length-weight relationships was used in analyzing individual growth, whereas length was for length frequency distribution in order to calculate population growth. The results showed that the Bombay duck growth was allometrically negative in station 2 and 3, whereas isometric in station 1.

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Fulton's condition factor varied between 0.93 - 0.99 in males and 0.94 - 0.98 in females, of which the smallest CF values were in May (male) and August (female). $L\infty$ values for males and females were alike 278.78 mm with K value of 0.51 and 0.38 for males and females, respectively. Fishing mortality (F) was larger than natural mortality, and the exploitation rate of 0.80 which far beyond the sustainable fishing of 0.5 (overfished).

Keywords: condition factor; exploitation rate; growth; individual growth; the bombay duck

1. Introduction

The Bombay duck (*Harpodon nehereus*, Hamilton 1822) is a highly economic fish species which is the main catch fishery product of Tarakan Municipality North Borneo Province. The catch has been inreasing since the last decade. According to Tarakan Fishery Statistic in 2011, in 2001 its production reached 58.80 tons, increased to 73.50 tons in 2007, and to 84.9 tons in 2010. Intensive utilization on this synodontids member might reduce its population size so that it will risk their sustainability. In fact, the local fishermen, had already presume on population depletion as it is clearly indicated by the reduction in size and catch at comparable effort compared to previous 5 – 10 yrs period. Based on these facts, appropriate management of this species is mandatory. Reference [1] stated that fishery management is aiming to increase and maintain the exploitation rate at that maximum yield sustainability level. The amount of harvest should be at the level of which population can replace the loss due to fishing.

Biological studies about *H. Nehereus* in Indonesia unfortunately has been very limited. Therefore, the facts on this species could only be compared with their siblings species in Bangladesh on the study of age and growth, condition factor [2], in southwest Taiwan on age and growth [3] and in Mumbai waters on their population dynamics [4].

The present study was intended to investigate the growth of the Bombay duck in which the data are of important scientific finding to determine how fast the fish grow and the recovery time of its population after exploitation. This study deals mainly with the exploration on both individual and population growth of *H. Nehereus* from which length size distribution data may fed to estimate the exploitation rate.

2. Materials and Methods

2.1. Sampling site and time allocation

The present study was conducted in Tarakan Islands waters within the coordinate 117.29’’ – 117.41’ E and 3.24’ – 3.28’ N during March 2013 to February 2014, of which sampling period was performed with monthly interval.

Based on fish distribution pattern, capture time, and geographic conditions of waters off northern part of the island, three sites has been determined as sampling station. Those sites are: Station 1: Fishing day-1, Tanjung Simaya (waters northeast of Pulau Tarakan, directly facing the open Sulawesi sea), Station 2: Fishing day-2, Tanjung Selayu, the north beach waters of the strait between Tarakan and Tibi island, where supplied mostly by freshwater runoff from Sesayap River and Station 3: Fishing day 3 and 4, Tanjung Juata, waters on the southwest beach, located inside the strait (Figure 1).

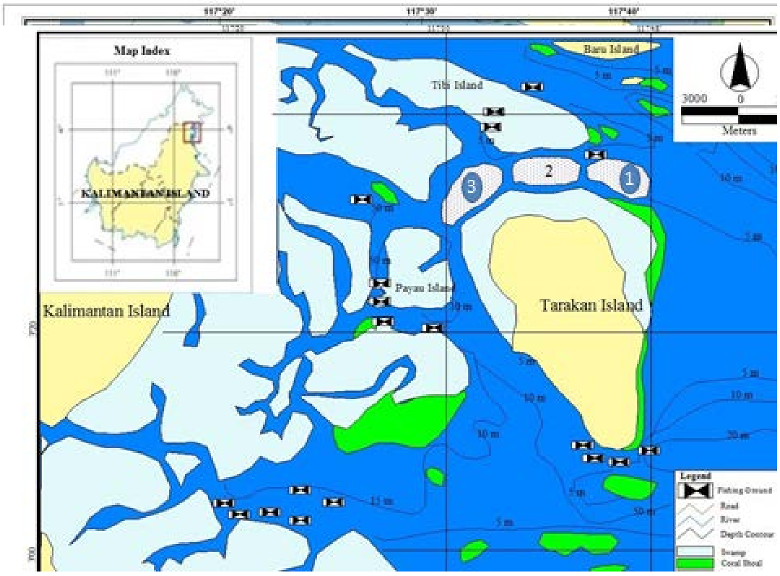

Figure1: Sampling location for *H. nehereus* in Tarakan Island waters. Numbers are sampling sites.

2.2. Sampling Protocol

At each sampling time, fishing was conducted with two replica on each station following the zig zag trawl route, using trawlers with a mesh size of the pocket, wing, and body of 1: 2 : 2 inch, respectively, with towing time of 30 minutes in each sub-station. On board, total captured were weighted and approximately 50 individual fish were randomly taken from each sub-station in case of sample was hihgly abundant (> 100 individual fish). Alternatively, all sample were taken if the catch less than 50 fishes. All specimens were preserved in a 5 – 10% formaldehyde solution, put into the container, and on land the sample were transported to laboratory for length and weight data measurement.

2.3. Data Analysis

Analysis was performed on 1,050 individual fish obtained during sampling in March 2013 to February 2014. Based on length-weight data, the individual fish growth is determined following an exponential formula [5] :

$$W = aL^b$$

Where : W = fish total weight (g)

L = fish total length (mm)

a and b = regression constant

The value of b is used to estimate the individual growth, in which hypotetically following a premise that: $b = 3$ indicates isometric growth (the length growth in line with the increasing weight). Otherwise if $b \neq 3$ stands for allometric growth. If $b > 3$: the weight gains faster than length (positive allometry), while oppositely $b < 3$(negative allometry).

Further exploration on length-weight dataof *H. nehereus* showed allometric growth pattern, therefore the Fulton's condition factor (K) is calculated based on [6], as follow:

$$K_n = \frac{W}{aL^b}$$

Where : K_n = Relative condition factor on each fish

W = Fish weight (g)

a, b = Constants

L = Fish total length (mm)

In estimating population growth, the total length is used to calculate the length requency distribution analysis and furtherly required to estimate growth using *von Bertalanffy* model according to the following formula [1]:

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

Where: L_t = Fish length at age t (mm)

L_∞ = Maximum length (mm)

K = Growth coefficient (t)

t_0 = Theoretical age of fish at zero length (year)

The values of L_∞ and K were calculated using ELEFAN 1 method readily available in FiSAT II program. The value of t_0 can be assumed by the following equation [1]:

$$Log -(t_0) = -0.3922 - 0.2752 \; Log \; L_\infty - 1.038 \; Log \; K$$

The determination of the group size was conducted by analyzing the length frequency data using ELEFAN I (*Electronic Length Frequencies Analysis*) program bundled in the FiSAT II (*FAO-ICLARM Stock Assessment Tool*) program package. Total mortality was determined using Z/K quotient technique and its modification, developed by Boverton and Holt in 1957. Z/K value could be determined if the values of L_∞, L_c and L are known using the equation of Boverton and Holt in [1]:

$$\frac{Z}{K} = \frac{(L_\infty - L)}{(L - L_c)}$$

Where: K = Growth coefficient in von Bertalanffy equation

L_∞ = Asymptotic fork length on von Bertalanffy growth equation

L = Fish average length at a certain age group

L_c = Fish length at first capture

Natural mortality rate (M) is determined using Pauly's empirical equation in 1980 as cited by [1], using the effect of annual average temperature (T) on fish natural mortality rate : $\ln M = -0.0152 - 0.279 \ln L_\infty + 0.6543 \ln K + 0.463 \ln T$

Where : M = Natural mortality

K = Growth coefficient in von Bertalanffy equation

L_∞= Asymptotic fork length on von Bertalanffy growth equation

T = Average water surface temperature (^oC)

Exploitation rate or death determination due to exploitation (F) is limited to the possibility of fish death due to exploitation in a certain period when every death factor contributes to the population. The fishing mortality rate (F) is calculated as the following: $F = Z - M$

Exploitation rate is determined by comparing fishing mortality (F) towards total mortality (Z) [1] :

$$E = \frac{F}{F + M} = \frac{F}{Z}$$

Fishing mortality rate (F) according to Gulland (1971) as cited by [1] is calculated as the function of $F_{optimum} = M$ and $E_{optimum} = 0.5$.

3. Results

3.1. Length-Weight relationship

All but in Tanjung Jaya Station, male and female of the Bombay duck showed negative growth allometry ($b < 3$). According to body length against weight, females and males at each station were insignificant in b-value ($P = 0.01$). In comparison to Tanjung Selayu and Tanjung Juata, fish in Tanjung Simaya demonstrated isometric growth pattern (Table 1).

Table 1: b-values of *H. nehereus* calculated from length-weight relatonship of three sampling sites in Tarakan Island waters

Station	Sex	n	R^2	T-count and ttab	b	Note
1 (Tanjung Simaya)	female	111	0.828	1.61 dan 1.98	2.802	Isometric
	male	134	0.810	1.92 dan 1.98	2.775	Isometric
2 (Tanjung Selayu)	female	152	0.816	2.87 dan 1.97	2.698	Allometric negative
	male	161	0.852	3.30 dan 1.97	2.705	Allometric negative
3 (Tanjung Juata)	female	245	0.834	4.87 dan 1.96	2.632	Allometric negative
	male	247	0.830	3.81 dan 1.96	2.703	Allometric negative
Total	female	507	0.827	5.56 dan 1.96	2.695	Allometric negative
	male	544	0.826	5.63 dan 1.96	2.700	Allometric negative

Having seen coefficient determination (R^2) values in Table 1, it is shown that length was able to explain > 80% of variation in weight. Head to head comparison in R^2 between two sexes were relatively alike.

The females have a determination coefficient ranged from 0.816 to 0.834 and reached 0.827 in total. For the males, determination coefficient ranged from 0.810 to 0.852 with a total value of 0.826. The study resulted that the captured fish in three stations are relatively uniform in size for both males and females with the largest average size found in station 1 (Figure 2).

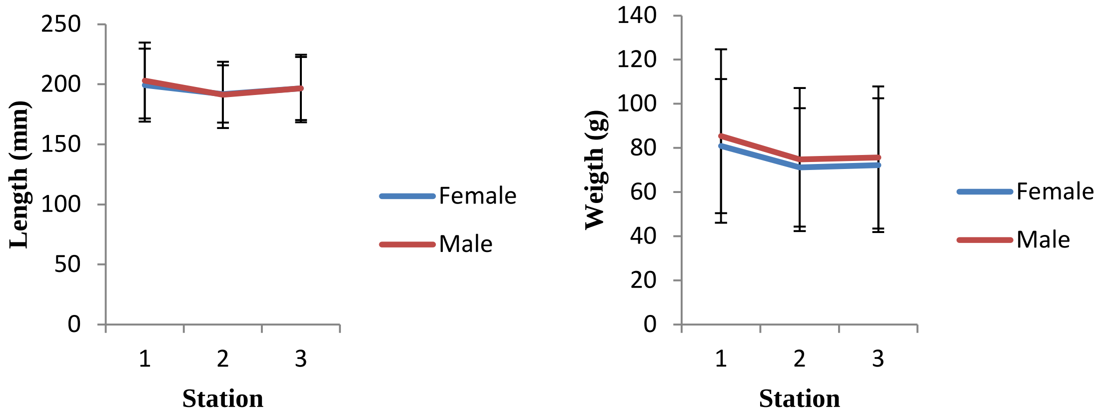

Figure 2: Size comparison in the *H. nehereus* at three stations in Tarakan waters

3.2. Condition Factor

Condition factors fluctuated every month for both male and female of the Bombay duck. It peaked in June but dropped to the lowest in May and August for the female, male, and its combination. Difference in male and female is barely noticeable or considered non-exist. From the observation site, a condition factor variation of male fishes ranged 0.93 – 0.99 and 0.94 – 0.98 for females. The smallest value was obtained from station 3 while the largest was found in station 2 for males and station 1 for females. The fish size recorded at station 1 was bigger than the other observation stations (Figure 3).

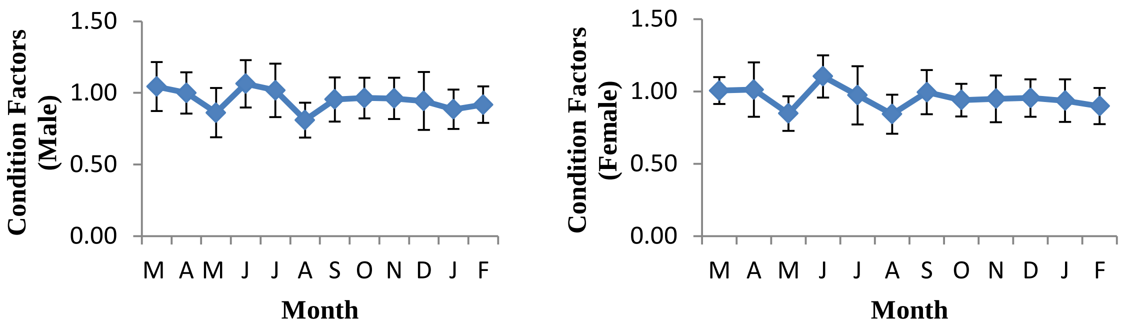

Figure 3: Condition factor (K) of male and female of the Bombay duck in Tarakan Island water

3.3. Population Growth

The distribution data on frequency of the Bombay duck fork length are provided in Figure 4. The length of the smallest captured fish class was 128 – 139 mm dominated by juveniles. The monthly measurement on distribution of this species showed no significant growth. For instance, in March the dominant class size was 152 – 163 mm for males and 176 – 199 mm for females, in April it shifted to 176 – 187 mm for both male and female. During fishing and spawning peak in December the dominant size was 236 – 247 mm shifting to 200 – 211 mm in males and 236 – 247 mm in females in January. The monthly size comparison of the Bombay duck is shown in the following Figure 4.

3.3. Asymptotic Growth

Asymptotic or infinitive growth illustrating the maximum size attained by the Bombay duck in Tarakan island waters is shown in Table 2 and Figure 5.

Table 2: Parameter of growth K, L∞, and t_0 male and female of Bombay duck

Parameter	Male	Female
K (per year)	0,38	0,51
L inf (mm)	278,78	278,78
to (per year)	-0,17	-0,23

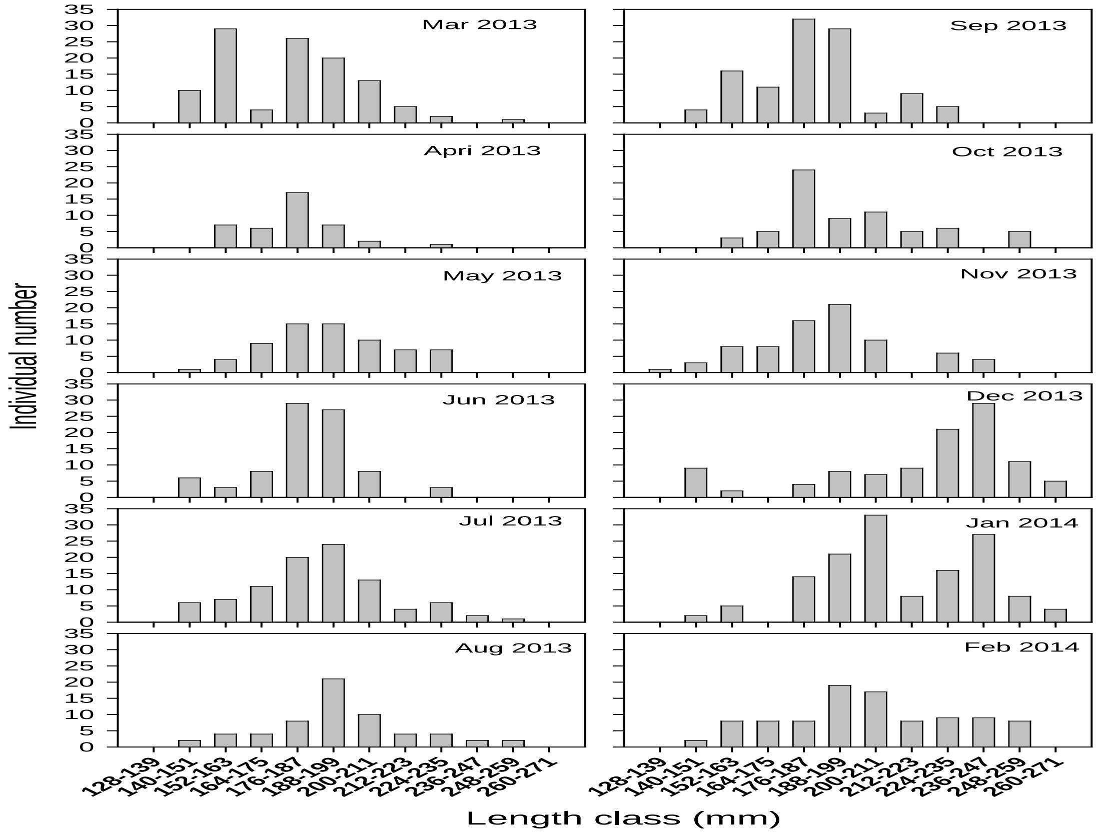

Figure 4: The fork length class frequency of the Bombay duck (*H. Nehereus*) in Tarakan island waters

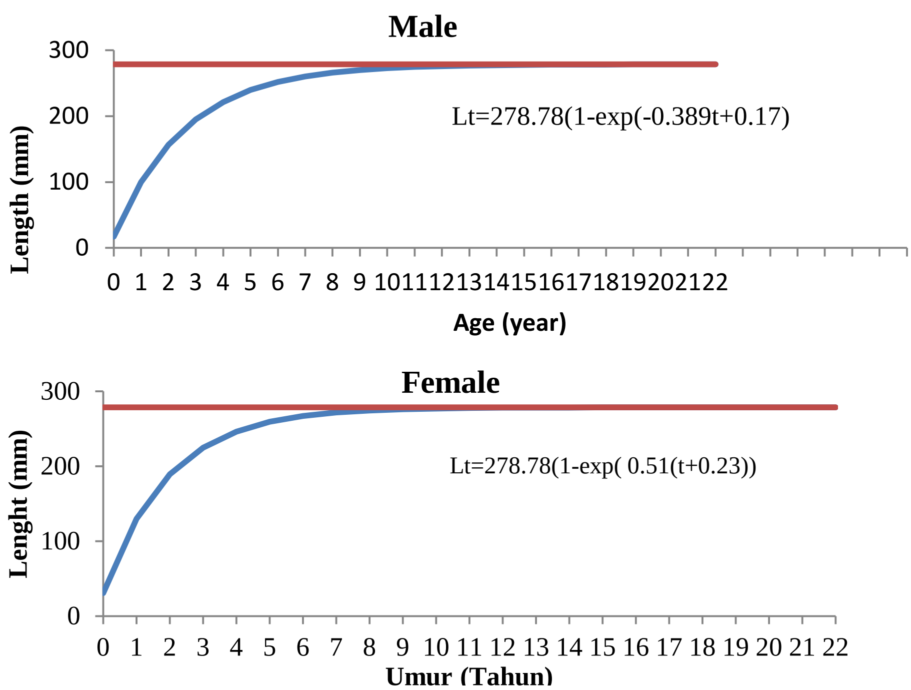

Figure 5: The asymptot growth of the Bombay duck (*H. nehereus*) in Tarakan island waters

The study resulted that growth indicators, namely length and weight distribution, condition factor, growth pattern, natural mortality, fishing mortality, total mortality, and exploitation rate of the Bombay duck among the three observation sites are relatively similar with the exception of condition factor which was recorded between 0.49 – 1.2 for female-s and 0.27 – 0.56 for males (Table 1). The asymptotic growth of female and male fishes showed an equal L∞ value of 278.78 mm while the annual t_0 for females and males are -0.17 and -0.23, respectively.

3.4. Exploitation Rate

The three observation sites showed a condition of overfishing as indicated by natural mortality, fishing mortality, total mortality, and exploitation rate in Table 3.

Table 3: Distribution of length – weight, condition factor, koefisien growth, natural mortality, fishing mortality, total mortality and eksploition rate at three stations in Tarakan waters

PG / St	Lenght ($\bar{X}$ + SD)		Weight ($\bar{X}$ + SD)		b		CF		K		M	F	Z	E
	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂				
1	199.19± 30.35	203.03± 31.59	80.87± 30.35	85.39± 39.28	2.802	2.775	0.98± 0.17	0.95± 0.20	1.2	0.56	0.58	2.47	3.06	0.81
2	191.88± 23.80	191.14± 27.56	71.16± 26.86	74.75± 32.36	2.698	2.705	0.97± 0.16	0.99± 0.16	0.49	0.27	0.45	0.73	1.17	0.62
3	196.47± 26.20	196.48± 28.03	72.17± 30.31	75.69± 32.25	2.632	2.703	0.94± 0.15	0.93± 0.16	1.2	0.41	0.42	0.65	1.07	0.61
Total	194.73± 25.97	196.51± 29.09	73.59± 29.47	77.81± 34.37	2.695	2.700	0.96± 0.16	0.95± 0.17	0.51	0.38	0.51	2.05	2.56	0.80

Note: PG; parameter of growth, St; station, b; constanta of regresi, FC; faktor condition, K; koefisien of growth, M; natural mortality, F; fishing mortality, Z; mortality total, E; eksploition rate

It is shown that growth coefficient was higher in female- compared to male for each station and total (Table 1). Fishing mortality in three observation stations ranged 0.65 – 2.47, bigger than the natural mortality of 0.42 – 0.58. The exploitation rate in the observation sites also showed overfishing condition with the biggest value of 0.81 found in station three.

4. Discussions

4.1. Growth Pattern and Condition Factor

Statistical analysis showed a strong correlation (r) between length and weight of the Bbombay duck. The value indicated that the increase of length will be followed by increasing of weight. Reference [7] stated that variation in exponential value (b) of the length – weight correlation is linked to age difference, gonad maturity, sex, geography, environmental condition, stomach content, disease, and parasitic pressure. Field observation showed that habitat differences in the form of various observation sites, sampling time, age, sex, and gonad maturity resulted in isometric and negative allometry growth pattern (Table 1). In addition, the variation of b value is caused by the difference in sample size and length [7]. This factor is also assumed to cause the different b value between stations and sexes of bombay duck in Tarakan island waters.

The study of the length-weight correlation showed that the growth pattern is generally negative allometry. Our result is in line with the result on Synodontidae family, i.e. *Saurida tumbil* in the Persian bay [8], *Saurida undosquamis* in Benghazi, Libya [9] and *Saurida tumbil* in Persian bay waters [10]. On the other hand, the positive allometric pattern was reported by [11] in the red sea in the same family of genus *Saurida*. The present study showed that negative allometric growth were noticed in stations two and three. This refers that the fish grow faster in length as opposed to weight. On the contrary, station one observed an isometric growth, showing a balance of growth in length and weight. The difference of growth pattern between stations probably affected by spawning season which occurring in June and December, make the fish appear more corpulent due to increasing gonad size. This is in accordance with [12] who reported that gonad becomes heavier until it reached the maximum size briefly prior to spawning.

The analysis result showed that the value of fish condition factor fluctuated every month on both male and female. Based on the observation month, the fluctuation for females ranged from 0.84 – 1.10 and 0.81 – 1.06 for males (Figure 3), whereas the fluctuation varies from 0.93 – 0.99 for males and 0.94 – 0.98 for females if the data are based on the observation sites. These values show some similarity with the value obtained in the neritic zone in Bangladesh, 0.5 – 1.4; [2]. This is further confirmed by [3] on *Harpadon microchir* where the females are bigger than the males. In Tarakan, the condition factor peaked in June for the males, females, and their combination while the lowest point was reported in May and August. In Bangladesh, the highest value is also obtained in June but the lowest value is obtained in July and December [2]. Differences between sexes are very narrow and considered nonexistent.

The lowest condition factor was observed at station three for both males and females while the highest value for males was observed in station two and station one for the females. The variation occurred, possibly due to gonad maturation stage and food availability as well as food energy content. Reference [13] stated that from the nutritional point of view, condition factor is an accumulation of fat and gonad maturation. Furthermore, according to Nikolsky in 1969 as cited by [13], condition factor indirectly showed the fish physiological condition affected by intrinsic factors (the gonad maturation and fat deposit). For instance, station one has abundant yellow drum fish and krills as live feeds while stations two and three are dominated by *Acetes*. Consequently, the protein content will vary between the feed and eventually in the bombay duck. Considering the bombay duck condition factor, Tarakan waters are very suitable for its growth. According to [14], condition factor is regularly used to determine habitat suitability of an organism.

4.2 Coefficient and Exploitation Rate

Based on the frequency distribution diagram, the description of growth where there is a shift in size did not occur (Figure 2). Therefore, it could be assumed that the migrating population every month is not always constant. The $L\infty$ value of the present study of 278.78 mm was equal for both males and females, higher than the value reported in Bangladesh: 240.48 mm [2], but lower than the value obtained from Saurashtra beach, India 410 mm and 425.2 mm and Mumbai, India 434 mm [15, 16 and 4]. The analysis on growth coefficient (K) in Tarakan showed that it is higher in females (0.52 per year) than males (0.38 per year). This is lower than the value obtained from Saurashtra beach, India; 0.762; and 0.749; [16, 15] for females and males, respectively). The value is much higher in Mumbai, India (0.85 per year and the neritic zone, Bangladesh 1.50 per year [4, 2]).

However, the lower growth coefficient was found from the same family but different genus of *Saurida undosquamis* in the Suez canal, Egypt (K = 0.26 with $L\infty$ = 35.56 cm, [17]. In Tarakan waters, the value is higher in males compared to the females. The cause is either internal or external. Internal factors include genetics that directly restrict the age and maximum body size [18], while external factors are environment and food availability. The environment will be a limiting factor if it is not kept in optimum condition since the fish will prefer to use the food for adaptation instead of growth. On the observation site, salinity is the most fluctuating external factor. The variety ranges of 11.54 - 26.40 ppt between time and observing station.

Analysis of exploitation rate resulted in a value of 0.80, equal to the value obtained on *Saurida undosquamis* in the Suez canal, Egypt (E = 0.8; [17]. It indicates that bombay duck in Tarakan exceeds the optimum exploitation rate of 0.5 and faces overfishing. It is also shown that bombay duck population are pressured due to very intensive fishing activity. This fact corresponds with the Tarakan statistic data, where production steadily increases from 58.80 tons in 2001 to 73.50 tons in 2007 and 84.9 tons in 2010 (Tarakan Fisheries Statistics, 2011). This showed that fishing mortality (2.05) far exceeds the natural mortality caused by disease, parasite, pollution, competition, and predation of 0.51. It was also confirmed by interviews with local fishermen who stated that the fish are continuously reduced in size and availability. From the biological aspect, the bombay duck in Tarakan also tends to reduce in the size upon first maturation compared to the ones found in Bengal bay, India. Analysis of size upon first maturation resulted that male gonads mature faster compared to females, with the length of 218 mm and 221 mm respectively. It is much smaller than reported by [15] of 244 mm. Maturity acceleration and size reduction during gonad maturation is one of the strategies that applied by a species in the pressed condition to preserve their population.

5. Conclusion

The Bombay duck growth was negative allometry. The growth rate of male fish is lower than the female in a similar asymptotic fork length. The exploitation rate of bombay duck in Tarakan island waters is already at the overfishing stage.

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