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Population Dynamics of the Naleh Fish *Barbonymus* sp. (Pisces: Cyprinidae) in Nagan River Waters, Aceh Province, Indonesia

Agung S. Batubara[2], Deni Efizon[3], Roza Elvyra[4] Syamsul Rizal[1,2] and Zainal A. Muchlisin[1,2*]

[1]*Faculty of Marine and Fisheries;* [2]*Doctoral Program in Mathematics and Sciences Application (DMAS), Graduate Program, Universitas Syiah Kuala, Banda Aceh;* [3]*Faculty of Fisheries and Marine Sciences,* [4]*Faculty of Sciences, Universitas Riau, Pekanbaru, Indonesia.*

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Abstract

The Naleh fish *Barbonymus* sp. is among the popular commercial fresh water fishes found in Indonesia; however, the population has drastically declined over the past decade. Necessarily, a conservation program needs to be established to gather information on the population dynamics to overcome this problem. The objective of this study is to analyze the population dynamics of the Naleh fish in Nagan River. The survey was conducted from January to December, 2016. In totality, three sampling locations were selected based on information from local fishermen. The Naleh fish was sampled using gillnets (mesh size 0.5 and 1.0 inches) and casting nets (mesh size 1.5 and 2.0 inches). A total of 761 fish samples were collected for the study. The von Bertalanffy (von Bertalanffy growth function) growth parameters were utilized to analyse the population dynamics of *Barbonymus* sp., using FISAT II (FAO-ICLARM Stock Assessment Tools-II). The results show the following population dynamics: Asymptotic length (L_∞) was 160.07mm, coefficient of growth (K) = 0.73 year^{-1}, growth performance index (Ø) = 4.27 year^{-1}, time at which length equals zero (t_0) = -0.022 year^{-1}, growth and age (Lt) = 2.55 year^{-1}, and optimum length of catch (L_{opt}) = 89.9mm. In addition, the total mortality rate (Z) was 2.802 year^{-1} with a natural mortality rate (M) =0.921 year^{-1}, fishing mortality rate (F) =1.88 year^{-1}, and exploitation rate (E) =0.67 year^{-1}. The conclusion has been drawn based on the E value analysis which displays that the exploitation rate of the Naleh fish has surpassed the sustainable limit based on the value of L_∞, K, t_0, Lt, L_{opt} of the dominant one-year-old fishes caught.

Keywords: von Bertalanffy, Growth, Dynamics, *Barbonymus*, Nagan Raya waters

1. Introduction

Nagan Raya is located in the western part of Aceh Province, Indonesia. This district houses three main rivers, namely Nagan River, Lamie River, and the Seumanyam River. It also has a large abundance of freshwater resources because of the vast waters present. According to Muchlisin *et al.* (2015), there are at least seventy-three species of freshwater fishes found in these rivers. The previous study by Muchlisin and Siti-Azizah (2009) reported that a total of 114 species of freshwater and brackish water fishes were recorded from several parts of Aceh province, Indonesia. Of these, forty-six species were categorized as fish suitable for consumption, seventeen species had aquaculture potency, and ten other species had ornamental fish potency (Muchlisin, 2013). One of the promising candidates for aquaculture is the Naleh fish *Barbonymus* sp. Based on the biometric analysis showed that the morphology of the Naleh fish is close to *the B. gonionotus* (Batubara *et al*., 2018), but the genetic analysis using *Mitochondrial Cytochrome c Oxidase Subunit I (COI)* or commonly known DNA barcoding revealed the Naleh fish is not a synonymous to *B. gonionotus*, and indicates a cryptic species (Batubara, 2019); Therefore, an intensive study is being performed to validate the taxonomic status of this fish.

The *Barbonymus* has several local names, for instance, it is called Naleh and Balee and Tawes in Aceh, Sulawesi and Java, respectively (Isa *et al*., 2012). While, Malaysian people call it lampam, and it is called Thai sharpunti in Bangladesh (Mondol *et al*., 2005; Mollah *et al.*, 2011; Hossain *et al*., 2016; Reza *et al.*, 2017). Additionally, it is internationally called the silver tinfoil barb (Fish Base, 2018). This species is a major target for fishermen in the inland waters of the Nagan Raya District.

However, apart from being considered as food for consumption, the Naleh fish has a great potency as an ornamental fish, because of its attractive colours, especially on its caudal and ventral fins (Chheng *et al*., 2004; Gante *et al*., 2008; Eslamloo *et al*., 2012; Isa *et al*., 2012; Muchlisin *et al*., 2015). Its diversity in use makes it a main target for local fishermen in Nagan Raya, Indonesia leading to a decreased population due to overfishing. Besides overfishing, the Naleh population is also affected by ecological destruction of the Nagan River watershed due to deforestation, sand and gold mining in the upper stream. According to Brierley and Kingsford (2009), environmental degradation has negative impacts and may inhibit the process of fish replenishment. According to

* Corresponding author. e-mail: muchlisinza@unsyiah.ac.id.

Maceda (2013), freshwater ecosystems face higher damage threats compared to other ecosystems in the world. Based on the International Union for the Conservation of Nature (IUCN), several species within *Barbonymus*, for example *B. gonionotus* is categorized as 'Least Concern' (Thinh *et al.*, 2012). However, the current population of the Naleh fish *Barbonymus* sp. in the Nagan Raya waters has decreased over the years (Personal communication with local fishermen of Nagan Raya). Accordingly, there is a need to evaluate the conservation status of the Naleh fish.

Information on the population dynamics is vital in determining the conservation status of fish (Lorenzen, 2005; Kinzey and Punt, 2008; Gislason *et al.*, 2010). Presently, the studies on the population dynamics of fishes focused on marine fishes; for example, Arrafi *et al.* (2016) and Jayabalan *et al.* (2014) studied the population dynamics of the Indian mackerel in western Aceh waters, Indonesia, and the Sohar Coast of Oman respectively. Al-Marzouqi *et al.* (2012) also studied the population dynamics of *Argyrops filamentosus* in Oman sea, the *Katsuwonus pelamis* in the Indian Ocean (Adam and Sibert, 2002), and *Gerres oblongus* in Laguna Jaffna, Sri Lanka (Shutharshan and Sivashanthini, 2011). Besides fishes, the study of the population dynamics has also been conducted on squids (*Sepioteuthis lessoniana*) from the South Sea of Sri Lanka (Charles and Sivashanthini, 2011) and shrimps in the Ivorian sea (Yacouba *et al.*, 2014). However, information on freshwater fish, especially from the tropical waters, was not available during the study. Hence, the objective of the present study is to analyze the population dynamics of the Naleh fish in Nagan River, Aceh Province, Indonesia.

2. Methods

2.1. Time and Location

The study was conducted in the Nagan Raya River from January to December 2016. The fish samples were analyzed in the Laboratory of Ichthyology, Faculty of Marine and Fisheries, Syiah Kuala University, Banda Aceh. The fish was taxonomically identified according to Kottelat *et al.* (1993).

2.2. Sampling Procedure

The sampling was conducted in three locations along the Nagan Raya River °16'25.25"N and 96°24'22.34"E; 4°17'4.73"N and 96°25'56.83"E; 4°16'48.49"N and 96°27'8.50"E) (Figure 1), while the sampling points were the locations suspected to contain a lot of Naleh fish based on information from local fishermen. The sampling was conducted two times weekly from 08.00 AM to 16.00 PM for twelve months. The fish was caught using casting nets (mesh size 0.5 and 1.0 inches), gillnets (mesh size 1.5 and 2.0 inches), and fishhooks. The sampled fishes were kept in an icebox (4^{o}C), and were transported to the laboratory of Syiah Kuala University for further analysis.

In the laboratory, the fish samples were measured to obtain a standard length nearest to mm using a digital caliper (Mitutoyo, CD-6CS. Error = 0.01 mm), and were weighed to measure the total body weight nearest to gram using a digital balance (Toledo, AB-204. Error= 0.01 g). Finally, the sample was preserved in a 10 % formalin solution.

2.3. Parameters Calculation

2.3.1. Length Frequency

The length frequency measurements were carried out to determine the number of fish based on the length class. For this purpose, the maximum and minimum length, mean, number of classes, intervals, differences, and class width were calculated. The length frequency analysis refers to Jin *et al.* (2015) as follows:

$Fi = ni/N_X 100$

Where Fi is length frequency (%), *ni* is the total number of fish at class length -*i*, and N is the total fish sample.

2.3.2. von Bertalanffy Growth Function

The von Bertalanffy growth function was analyzed using FISAT II (FAO-ICLARM Stock Assessment Tools-II). The growth parameter was calculated using the ELEFAN-I method. This calculation gave an asymptotic length value (L_∞) and coefficient of von Bertalanffy growth function (K). Moreover, the theoretical age at fish length-0 was calculated based on Pauly (1980) as follows: Log (t_0) = -0.3952-0.2752 Log (L_∞)-1.038-Log (K). Where t_0 is the theoretical age at fish length-0, L_∞ is asymptotic length, and K is growth co efficient.

2.3.3. Total Mortality Rate

The total mortality rate (Z) was calculated using FISAT II based on Length-coverted Catch Curve method.

2.3.3.1. Natural Mortality Rate

The natural mortality rate (M) was calculated based on Pauly (1980):

$Log(M)=-0.0066-0.279Log(L\infty)+0.6543Log(K)+0.4634Log(T)$

Where M is the natural mortality rate, L∞ is infinity or asymptotic length, K is the growth coefficient, and T is the average temperature of the waters/habitat.

2.3.3.2. Fishing Mortality Rate

The fishing mortality rate (F) was calculated based on Pauly (1980) as follows:

$F = Z-M$

Where Z is the total mortality rate, and M is the natural mortality rate.

2.3.3.3. Exploitation Rate

The exploitation rate (E) was calculated based on Sparred and Venema (1992) as follows:

$E = F/Z$

Where E is the exploitation rate, F is the fishing mortality rate, and Z is the total mortality rate.

2.3.4. The Optimum Length of the fish caught and recruitment pattern

The optimum length of the fishes caught (L_{opt}) was calculated based on Froese and Binohlan (2000) as follows: $L_{opt} = 3*L_\infty/(3+M/K)$, where L_{opt} is the optimum length of the fish caught, M is the natural mortality rate, $L_\infty$is infinity or asymptotic length, and K is the growth coefficient. The recruitment pattern was performed using FISAT II by inputting the L_∞, K and t_0 values into the growth parameter inputs and graph menu.

3. Results

A total of 761 samples of *Barbonymus* sp. were recorded throughout the study period (twelve months). The fish samples were divided into eleven length classes. The minimum length was 48mm, while the maximum length was 167.07 mm, and the average length was 116.93 mm (Figure 2a). The range was 99 mm with an interval of 49.5mm. A large proportion of the fish samples (31.67 %) had a class length of 88-97 mm and an estimated age of one year (Figure 2a, Figure 3b). The results showed that the number of fish decreased with the increasing class length (Figure 2a); therefore, the optimum class length for fishing was 88-97 mm.

The results revealed that the growth coefficient value (K) was 0.730 year^{-1}which indicates that the growth rate reaches 73 mm year^{-1}. The infinity or asymptotic length (L_∞) showed that the maximum length of the Naleh fish was 160.07 mm (Figure 3a).

The analysis of the growth length and age of the samples revealed that the age of the fish samples ranged between one and five years, while the fish attained their maximum length at about five years (Figure 3b). The mortality rate is about 2.802 year^{-1}and is comprised of the natural mortality rate (0.921 year^{-1}), fishing mortality rate (1.880 year^{-1}), and the exploitation mortality rate (0.670 year^{-1}) (Table 1). The recruitment pattern analysis shows that recruitment occurred over the year, with the higher recruitment occurring in April (15.32 %), and the lowest recruitment occurring in August (2.79 %) (Figure 4b). These data indicate that the Naleh fish spawns over the year except in December (Figure 4b). However, this finding should be confirmed with the gonadosomatic index of the fish, and this study is currently ongoing.

Table 1. Population dynamics of the Naleh fish *Barbonymus* sp. in the Nagan Raya River, Aceh Province, Indonesia

No.	Parameters	Value
1	Infinity or Asymptotic length (L_∞)	160.07 mm
2	The optimum fishing length (L_{opt})	89.9 mm
3	Growth coefficient (K)	0.730 year^{-1}
4	Total mortality rate (Z)	2.802 year^{-1}
5	Natural mortality rate (M)	0.921 year^{-1}
6	Fishing mortality rate (F)	1.880 year^{-1}
7	Exploitation rate (E)	0.67 year^{-1}

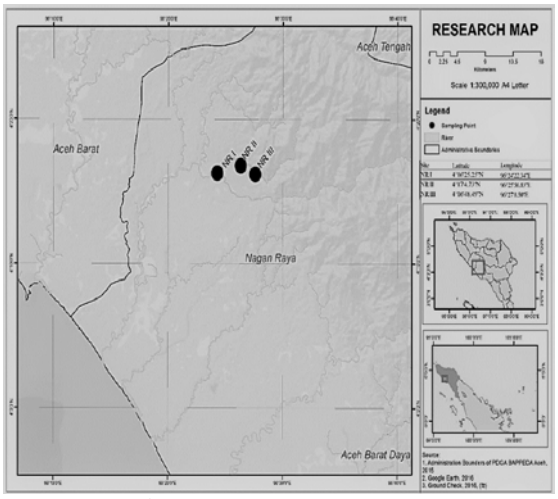

Figure 1. Map of the Nagan Raya District, Aceh Province, Indonesia showing the location sampling (black dots)

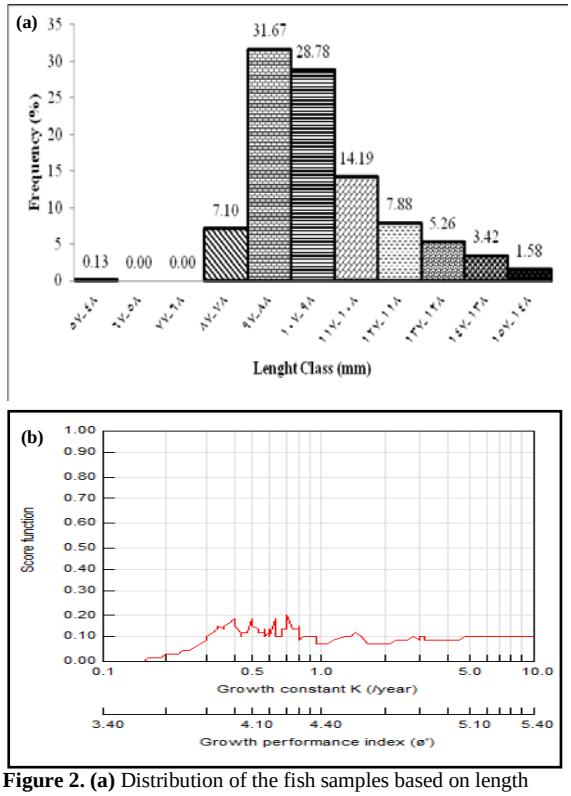

Figure 2. (a) Distribution of the fish samples based on length classes (N= 761) with the optimum length (L_{opt}) of 89.9 mm, **(b)** the estimation of the growth coefficient (K) was 0.730 year^{-1} and growth capable index (Ø) was 4.27 year^{-1} of the Naleh fish *Barbonymus* sp. in Nagan Raya River, Aceh Province, Indonesia

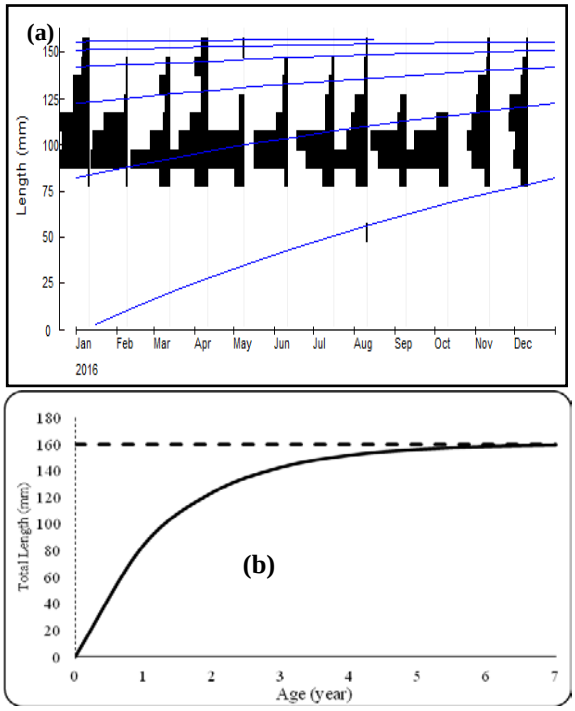

Figure 3. (a) Growth parameters estimation (L∞ = 160.7 cm and K = 0.730 year^{-1}); **(b)** the curve of the length growth and age estimation (t_0 = -0.022 and Lt = 2.55 year^{-1}) of the Naleh fish *Barbonymus* sp. in the Nagan Raya River, Aceh Province, Indonesia

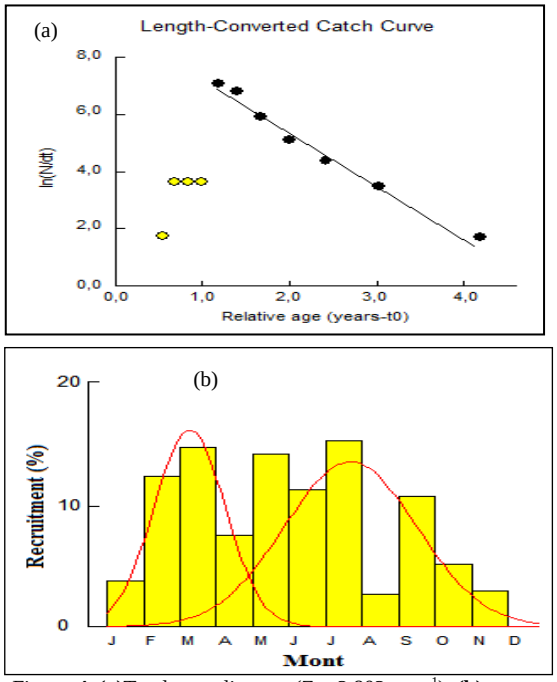

Figure 4. (a) Total mortality rate (Z = 2.802 year^{-1}); **(b)** Percentage of recruitment every month for one year of the Naleh fish *Barbonymus* sp. in the Nagan Raya River, Aceh Province, Indonesia

4. Discussion

The study shows that the majority of the fish samples were between the class length of 88-97 mm, and the optimum fish length is 89.9 mm, indicating that the length was within the limit. The study also revealed that most of the samples were one-year-old (Figure 3b). The estimation of the length to the age is about 2.55 mm year^{-1} with the infinity or asymptotic length as 160.07 mm. The results showed only few class lengths being above 88-97mm. This indicates that only few Naleh fish attained sizes above 97mm. The results are in accordance with the statement of Tyrrell *et al*. (2011) that the population of fish decreases with the increasing length because of the increase in the probability of mortality due to fishing and diseases.

In comparison, the asymptotic length of the Naleh fish *Barbonymus* sp. in the Nagan River is lower compared to that of the fish in the Mekong River, Cambodia (Chheng *et al.*, 2004) and the *B. schwanenfeldii* in Pedu Dam, Malaysia (Isa *et al*., 2012) with an infinity length of 160.07mm and 309.5mm, respectively. According to Froese and Binohlan (2000), the fish population is threatened if the fish harvest is small. This may be attributed to ecological degradation and overfishing. This indication is in agreement with several previous studies in *Barbonymus* from different locations. For instance, Hardjamulia *et al.* (1988) reported that the size of harvested *B. gonionotus* decreased from 405mm in 1999 to 340 mm in 2009 (Sastrawaha and Pilasamorn, 2009), then, it continued to decrease to 211 mm in 2010 (Garcia, 2010), and 209mm in 2016 (Hossain *et al.*, 2016) and as recorded in this study to 160.07mm in 2016.

The total mortality of the Naleh fish in the Nagan River is 2.802 year^{-1} with a fishing mortality of 1.880 year^{-1} which is higher than the natural mortality rate (0.921 year^{-1}). Moreover, the ratio M (0.921 year^{-1}) and K (0.730 year^{-1}) was 1.263; this value indicates that the Naleh fish population is threatened by intensive and unfriendly fishing practices, and the destruction of habitat as observed during the study. A similar phenomenon was also reported in Depik fish *Rasbora tawarensis* the endemic species in Lake Laut Tawar, Aceh Province, Indonesia (Muchlisin *et al*., 2011). According to Al-Marzouqi *et al.* (2012), the normal ratio M/K ranges from 1.0 to 2.5. The exploitation rate (E) of the Naleh fish in this study was 0.67 year^{-1}, which means that the total mortality was 67 %, as a result of fishing activities excluding natural mortality. The optimal value of exploitation rate (E) is 0.5 (Jayabalan *et al.*, 2014) with the estimation that the sustainable yield is optimized at F = M (Gulland, 1971). According to Isa *et al.* (2012), if the exploitation rate (E) is higher than 0.5 year^{-1},this indicates that the new recruitment has a negative correlation with the E value (overfishing).

Sparre and Venema (1992) stated that the natural mortality rate is influenced by predation, diseases, stress, spawning, and old age. The study revealed that the value of the rate of exploitation was 0.670 year^{-1}. This value was higher than the recommended maximum exploitation of 0.5 year^{-1}, which indicates that the exploitation has passed the limit. This is supported by Gabche and Hockey (1995) who explained that if the exploitation rate is higher than 0.5 year^{-1}, it means that the exploitation has crossed the sustainable exploitation limit. According to Bostford *et al.* (1997), overfishing occurs when the fishing activities supersede the recruitment capacity. Overfishing is a major problem worldwide because it can potentially lead to extinction, and a reduced biodiversity of the fishes (Coleman and Williams, 2002).

Furthermore, the recruitment pattern of the Naleh fish occurs over the year except in December, and the peak of

recruitment is in July. Therefore, more studies on reproductive biology are needed to confirm this finding. A similar trend is also reported by Jasmine and Begum (2016) that *B. gonionotus* in the Padma River, Bangladesh spawns from April to July with the peak season being in June.

5. Conclusion

It can be concluded that the recorded maximum length of the Naleh fish was 89.9 with an age estimation of one year. The optimum fish length was 160.07mm, and this length can be attained when the fish is at least five years old. The exploitation rate (E = 0.67 year^{-1}) has passed the sustainable limit (overexploitation), which means that overfishing already exists.

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