Population dynamics of climbing perch (*Anabas testudineus*, Bloch 1792) fish resources in south Kalimantan, Indonesia

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Abstract. One of the local fish resources that is exploited intensively in South Kalimantan is climbing perch, locally known as climbing perch (*Anabas testudineus).* The aim of this study was to analyze the parameters of a growth and mortality of *A. testudineus* in South Kalimantan. The samples were collected during July-October 2020 from three different locations of South Kalimantan. Survey-dependent sampling technique was used to gather the data which applied the von Bertalanffy approach as a measurement of fish growth and the FISAT II program was used to measure the mortality. The fish growth parameters showed that the K value was 1.5, 0.9, and 0.5 year^{-1}, the L L∞ was 202.13, 151.20, and 191.63 mm and the t_0 value -0.8, -0.5, -0.1 year^{-1} in the Bararawa, Tungkaran and Pantai Harapan swamps, respectively. The highest recruits in the Bararawa and the Tungkaran swamp were once a year, respectively, in June (36.29%) and August (20.87%), and the highest recruits in Pantai Harapan swamp were in May (17.63%) and July (15.26%). The natural mortality rate (M) was 1.41, 1.17 and 10.67 year^{-1}, the fishing mortality rate (F) was 6.68, 1.89, and 0.64 year^{-1} and the exploitation rate (E) was 0.83, 0.62, and 0.49 year^{-1} in the Bararawa, Tungkaran and Pantai Harapan swamps, respectively.
Key Words: stock assessment, growth parameters, mortality*,* FISAT II.

Introduction. The species of fish in tropical waters is varied compared to those in temperate climates, and many of them have not been identified (Brown 2014). Kalimantan waters have the highest varieties of fish species in Asia (Winemiller et al 2008) and the South Kalimantan have utilization potential waters about 1 million ha. The potential of fishery resources is utilized by the community by exploiting them through fishing activities, targeting local fish. The Department of Marine Affairs and Fisheries of South Kalimantan Province (2019) stated that the level of exploitation of public water fish resources in 2018 reached 75,696.71 tons. In South Kalimantan, fishing activities are intensive since the need of fish protein is higher than other animal protein. The Central Bureau of Statistics (Ministry of Marine Affairs and Fisheries Republic Indonesia 2022) stated that fish consumption level of South Kalimantan is classified as high (61.91 kg capita^{-1}) in 2019. Four kinds of local fish that are used as the main consumption of the community include climbing perch, locally known as Papuyu (*Anabas testudineus*), striped snakehead, known as Gabus (*Channa striata*), rasbora, known as Seluang (*Rasbora* sp.), and three spot gourami, known as Sepat (*Trichogaster trichopterus*). In addition, *A. testudineus* is one of the local fish resources which is intensively exploited in South Kalimantan. The catch volume of *A. testudineus* in the mainland waters of South Kalimantan in 2020 was of 13,814.08 tons, with a production value of 470 million (Ministry of Marine Affairs and Fisheries Republic Indonesia 2022).

A. testudineus fish is a renewable resource. This means that if the fish resource is partially extracted, only the remaining fish stock will have the ability to breed (Nikijuluw 2002), in order to maintain the sustainability of this kind of fish stock. The mandate of the Law of the Republic of Indonesia Number 31 year 2004, Chapter IV Article 6 regulates the fisheries management to achieve optimal and sustainable benefits and to ensure the sustainability of fish resources (Republic of Indonesia 2004). Overfishing is one of the main causes of fish population decline, and has far-reaching impacts. In fact, freshwater fish are threatened by a number of human activities, which can have serious impacts on the species and their associated food sources (Benstead 2019). Fish management resource needs to be carried out as one of the precautionary approaches to preserve fish resources (FAO 1995; Neala et al 2009; Nikijuluw 2001; Republic of Indonesia 2007). A fisheries management decision must be based on scientific evidence (Allan et al 2007; FAO 1995; Pinkerton 1988). Research related to tropical river water fish lags behind research in temperate waters (Dudgeon 2000; Matthews & Heins 1987; Winemiller et al 2008). Furthermore, nowadays the public waters management in world is still poor. Scientific information about waters management and the distribution of conservation efforts in all tropical areas have not been covered (Dudgeon 2003; Moulton & Wantzen 2006; Pringle et al 2000).

Therefore, the aim of this work was to provide scientific data regarding the stock assessment of *A. testudineus* resources in South Kalimantan, intended to improve the resources management, based on a holistic and analytical stock analysis (Sparre & Venema 1999).

Material and Method

Sampling sites. The sampling was conducted in three locations: (1) Bararawa swamp waters in Hulu Sungai Utara Regency, (2) Tungkaran swamp waters in Banjar Regency and (3) Harapan Beach swamp waters in Tanah Laut Regency (Figure 1). Bararawa swamp waters in Hulu Sungai Utara Regency represent the rivers' upstream swamp area of South Kalimantan, Tungkaran Swamp Waters in Banjar Regency represent the middle swamp region of South Kalimantan and Pantai Harapan swamp waters in Tanah Laut Regency represent the river downstream swamp area of South Kalimantan.

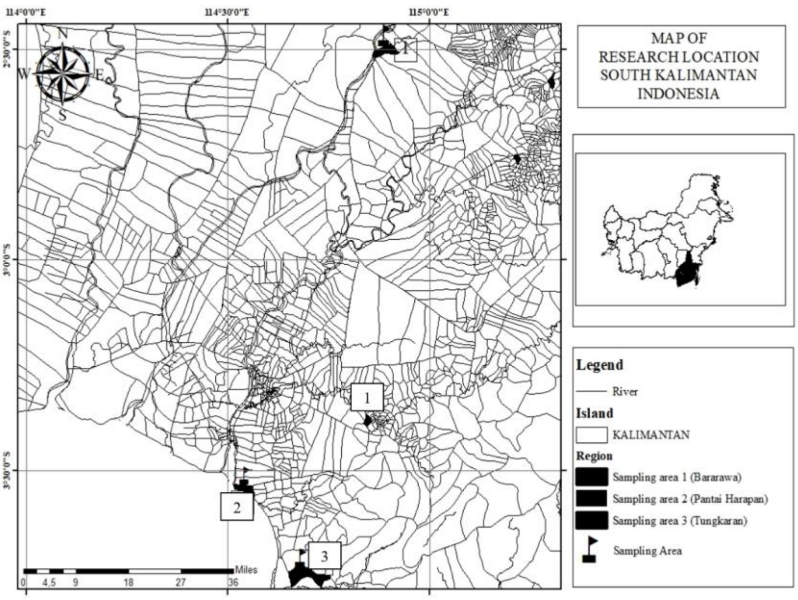

Figure 1. Research site map.

Data collection. Data collection for stock analysis was carried out by randomly taking fish samples using the Ford-Walford plot method, once a month, during four months. Stock parameters use secondary data time series of production and fishing effort from the Provincial and District/City Fisheries and Marine Services of South Kalimantan.

Data analysis

Fish growth parameters. The measurement of fish growth parameters was using Ford-Walford plot method. This method measured growth parameters including $L\infty$, K, and t_o

from the growth model, the following is the formula developed by von Bertalanffy (Sparre & Venema 1999):

$$Lt = L_\infty\{1 - e^{-k(t-to)}\}$$

Where:
Lt - length of fish at age t (unit of time);
L∞ - theoretical maximum length (asymptotic length);
K - growth coefficient (per unit time);
t_0 - theoretical age when length is zero.

Using the approach developed by Gulland and Holt, the parameters k and L_∞ are estimated with the following formulation (Sparre & Venema 1999):

$$\Delta L/\Delta t = a - b \ \ (L_t + L_{t+1})/2$$

Where:
$\Delta L/\Delta t$ - length growth per period;
$(L_t + L_{t+1})/2$ - mean of length for the period;
a, b - constant.

The theoretical age of fish when the length is equal to 0 (t_0) is measured using Pauly's (1983) empirical equation:

$$\ln(-t_0) = -0.3922 - 0.2752 \ln L_\infty -1.038 \ln k$$

Parameter values of L_∞ and K were obtained using the approach developed by Pauly (1983) and by processing fish frequency distribution data using the ELEFAN I (Electronic Length Frequency Analysis) method, in the FISAT II program. The fish recruitment pattern was obtained by inputting data L_∞, K and t_0.

Mortality and exploitation rate. Total mortality was measured using (Beverton & Holt's (1957) theory, with the assumption that fish samples were obtained from a stable population with new additions and a constant mortality rate and followed Von Bertalannfy growth model. The value of Z/K (total mortality per growth rate) can be determined by the following equation, when the values of L_∞, L and Lc are known (Sparre & Venema 1999):

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

or the total mortality by the following formula, when the value of L' is known (Sparre & Venema 1999):

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

Where:
Z - total mortality;
K - fish growth rate;
L_∞ - maximum fish length/ asymptotic length in Von Bertalannfy's equation.
L - average length of fish in a certain age group;
Lc - length of the first fish caught;
L' - the length of the smallest fish in the sample, with a calculated amount.

Determination of natural mortality rate (M) using Pauly's (1983) empirical formula as follows:

$$\ln M = - 0.0152 - 0.279 \ln L_\infty + 0.6543 \ln K + 0.463 \ln T$$

Where:
M - natural mortality; M = e $^{(\ln M)}$;
L_∞ - maximum length of fish/asymptotic length in the Von Bertalanffy growth equation;
T - monthly average water surface temperature (°C).

The fishing mortality rate (F) is determined by the formula (Sparre & Venema 1999):

$$F = Z - M$$

The exploitation rate (E) was obtained by comparing the fishing mortality with the total mortality, as follows (Pauly 1984):

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

Meanwhile, the fishing mortality rate (F) or the optimum exploitation rate according to Gulland (1971) is as follows:

$$F_{optimum} = M \text{ and } E_{optimum} = 0.5$$

Results

Fish growth parameters. Regarding the aims of this research, the growth curve of *A. testudineus* based on the Von Bartalanffy method can be seen in Figure 2.

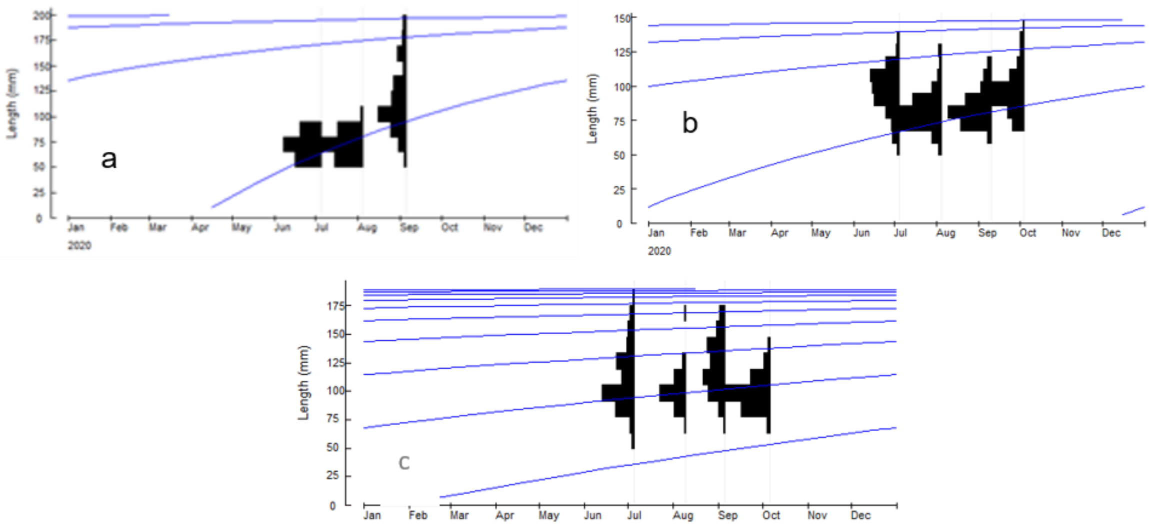

Figure 2. Growth curve of *Anabas testudineus* using Von Bartalanffy method. (a) Bararawa swamp waters, (b) Tungkaran Swamp Waters, (c) Pantai Harapan swamp waters.

Based on Figure 2, it can be said that the parameter of *A. testudineus* fish growth value in Bararawa swamp waters (K value) was 1.5 year^{-1}, L∞ value was 202.13 mm, and the value of t_0 using Pauly's (1983) empirical equation was -0.8 years. In Tungkaran swamp waters, the growth parameter of *A. testudineus*, K value was 0.9 year^{-1}, L∞ value was 151.20 mm, and the value of t_0 Pauly's (1983) empirical equation was -0.5 years. The parameter value of *A. testudineus* fish growth in the Pantai Harapan swamp waters, K value was 0.5 year^{-1}, L∞ value was 191.63 mm, and the value of t_0, from Pauly's (1983) empirical equation, was -0.1 years.

Recruitment (adding new individuals). The result of recruitment (adding new individuals) can be seen in Figure 3.

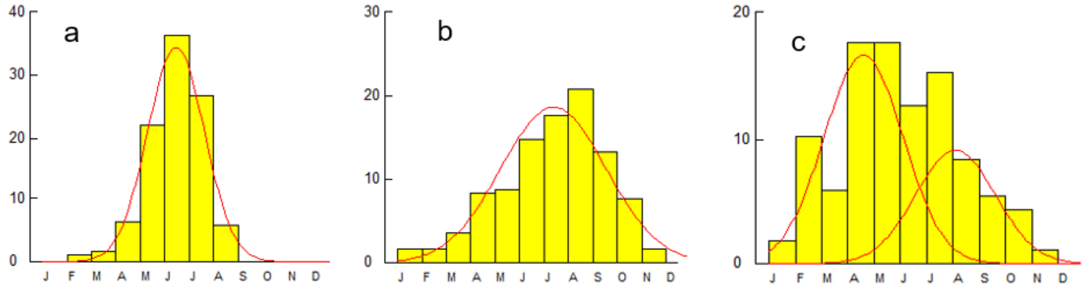

Figure 3. The pattern of new individuals annually. (a) Bararawa swamp waters, (b) Tungkaran Swamp Waters, (c) Pantai Harapan swamp waters.

Figure 3 shows that the pattern of fish recruitment at all locations shows that recruitment occurred throughout the year. Peak recruitment in Bararawa swamp waters and Tungkaran swamp waters occurred once a year, while in Pantai Harapan swamp waters occurred twice a year. The peak recruitment in Bararawa swamp waters occurred in June (36.29%). The peak recruitment in Tungkaran swamp waters happened in August (20.87%). In Pantai Harapan swamp waters, the peak recruitment happened in May (17.63%) and in July (15.26%).

Mortality and exploitation rate. Based on the analysis result using the FISAT II program, the value of the natural mortality rate (M) of *A. testudineus* in Bararawa Swamp Waters, Tungkaran swamp waters and Pantai Harapan Swamp Waters was 1.41, 1.17 and 0.67 year^{-1}, respectively. The fishing mortality rate (F) in Bararawa swamp waters, Tungkaran swamp waters and Pantai Harapan swamp waters was 6.68, 1.89 and 0.64 year^{-1}, respectively. Meanwhile, the exploitation rate (E) in Bararawa swamp waters was 0.83 year^{-1}, in Tungkaran swamp waters it was 0.62 year^{-1} and in Pantai Harapan swamp waters it was 0.49 year^{-1}. Details on the mortality and exploitation rate can be seen on Figure 4.

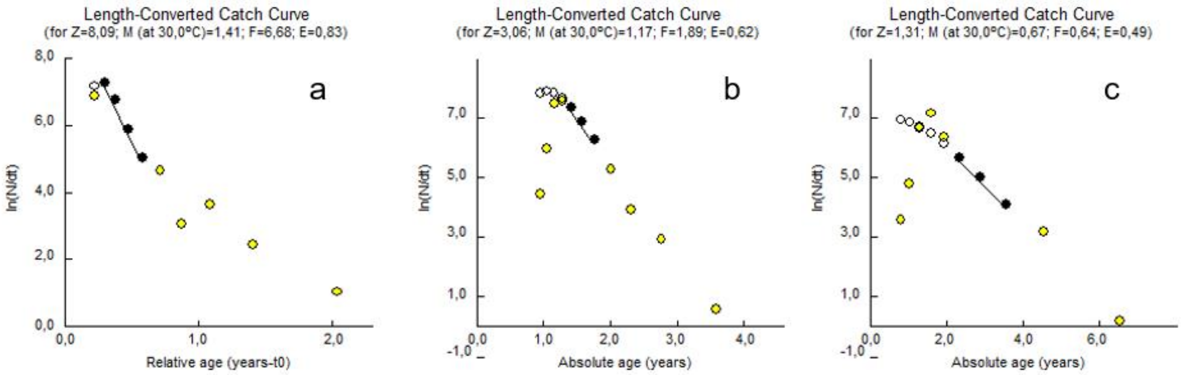

Figure 4. The curve of the catch of *Anabas testudineus* fish, which was linearized based on the length of compositional data. (a) in Bararawa swamp waters, (b) in Tungkaran swamp waters, (c) in Pantai Harapan swamp waters.

Discussion. Gulland (1969) and Widodo (2006) explained that in analyzing a population dynamic, the information that is needed is the mortality rate in an exploited fishery activity. Information on mortality and exploitation rates is one of the basics in managing fish resource stocks (Dodds 2002). The measured mortality parameters were the natural mortality rate (M), the fishing mortality rate (F) and the total mortality rate (Z). The natural mortality rate was measured using Pauly's (1983) empirical approach which showed the effect of annual temperature. The total mortality rate (Z) was estimated with a linearized catch curve based on fish length data and it was assumed that the population had a stable age (Sparre & Venema 1999). Furthermore, the fishing mortality (F) was measured by subtracting Z by M.

According to Pauly (1983) the natural mortality (M) of fish is declared large when the M value reaches 1.5 year^{-1}. Based on this theory, although the natural mortality in Bararawa is approaching this category, it is still under 1.5 year^{-1}. Garcia (1988) stated that in properly developed fisheries , fishing activities and efforts have been stable over a long period of time. The concept of optimum fishing rate developed by Pauly (1983) stated that the optimum fishing rate is achieved if the value is equal to the value of the natural mortality rate ($F_{optimum}$=M). According to Gulland (1969), if the value of F is higher than M (F>M), then the status of the fishery has reached over exploited. Based on this theory, it can be concluded that the value of the mortality fishing rate of *A. testudineus* in Bararawa and Tungkaran swamp waters categorized as over exploited (F>M), while the in Pantai Harapan swamp waters is categorized as under exploited.

Besides, the concept of the optimum exploitation rate was developed by Gulland (1969) and Pauly (1983), who stated that its achievement is indicated by a value of 0.5 year^{-1}. Referring to the concept of the optimum exploitation rate, the exploitation rate of *A. testudineus* at two of the research locations, Bararawa and Tungkaran swamp waters, has reached a status of over exploited, while in Pantai Harapan swamp waters, it reached the threshold level, since the value of the optimum exploitation is 0.5 year^{-1}.

Stock management strategies in areas with over exploited status recommend to reduce the fishing effort (number of fishing gear units and or fishing trips), as an anticipatory measure against threats to the sustainability of fish resources. Dudgeon et al (2006) stated that most freshwater fish in Asia are threatened by fish extinction as a result of overfishing mortality. Resources depletion due to marine species extinction events are one of the main current concerns of scientists and policy makers (Allan et al 2007). Therefore, regarding the overexploited *A. testudineus* resources in two out of three locations, it was suggested to reduce the fishing effort, (number of fishing gear and fishing trips), in order to better manage the stock of *A. testudineus*. Meanwhile, at the location that has an optimum status, it was suggested to limit the fishing effort.related to the

Conclusions. The findings of this study can be used as a basis for developing policies related to the exploitation of *A. testudineus* in South Kalimantan, ensuring that the species' exploitation remains sustainable and avoids extinction. A restrictive policy of catching *A. testudineus* is recommended, so that the species can be maintained in nature.

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Conflict of interest. The authors declare no conflict of interest.

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