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Estimation of Growth Parameter on Sailfin Catfish (*Pterygoplichthys pardalis*) in Bengawan Solo River, Central Java Province

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Abstract. Bengawan Solo river 548.53 km is the longest river in Java Island Indonesia, which crosses provinces of Central Java and East Java. Bengawan Solo river is heavily polluted by agricultural, industrial and domestic wastes, especially in Surakarta Residence, Central Java. The impacts of pollution in Bengawan Solo river are poor water quality, the population of native fish has declined sharply and some were almost extinct. The fish that develop was Sailfin catfish (*Pterygoplichthys pardalis*) because these fish were resistant to pollution. The study aimed to determine the growth parameters of Sailfin catfish (*P. pardalis*) in Bengawan Solo river. Estimation of growth parameter using length frequency data analysis was done using the FISAT program package. The results of growth parameters of Sailfin catfish (*P. pardalis*) showed that infinity length (L∞) = 41.75 cm; acceleration of growth (K) = 0.48 cm/year. Natural mortality (M) = 1,1; fishing mortality (F) = 2.47; and total mortality (Z) = 3.57. Exploitation rate (E) = 0.69. The conclusion is the fishing mortality of Sailfin catfish is quite high, while natural mortality is low because the fish are resistant to pollution.

1. Introduction

The Bengawan Solo River is one of the major rivers in Indonesia and the longest in Java with a length of 548.53 km, crossing two provinces, namely Central Java and East Java. The total area of the Bengawan Solo river is ± 19,778 km². It consists of four river basins, namely the Bengawan Solo Watershed with an area of ± 16,100 km², the Grindulu River and Lorog River Basins in Pacitan covering an area of ± 1,517 km², the small watershed in the north coast area of ± 1,441 km² and the Kali Lamong watershed covering an area of ± 720 km² [1].

Most of the conditions of the Bengawan Solo river have been light to heavy pollution caused by agricultural, industrial and household waste, especially in Sragen Regency, Central Java. [2] reported that water quality between Solo and Sragen was heavily polluted with dissolved oxygen levels less than 2 mg/L, high carbon dioxide (8.8–34.32 mg/L), free NH3-N (0.2 mg/L), high COD (1.64–172 mg/L), high phenol (0.087–1.431 mg/L), and high fat oil (2.6–54.6 mg/L). Indications of decreasing water quality in Bengawan Solo are increasingly and expanding pollutant in the river. Heavy pollution

starts from Karanganyar with an indication of black water, foul smelling, with a concentration of DO (0.8–3.2 mg/L), BOD (41.2–88.3 mg/L), COD (102.9–147.1 mg/L), H_2S (0.44 –0.840 mg/L) [3, 4].

The impact of the poor quality of Bengawan Solo river affects the life of aquatic biota, especially fish. The population and diversity of native fish species have decreased sharply and some are almost extinct. Fish that develop are Sailfin catfish (*Pterygoplichthys pardalis*) because they are resistant to pollution [5, 6, 7]. Its ability to survive in poor water conditions, small flow, and very low dissolved oxygen concentrations because it has additional respiratory organ (Labyrinth) if dissolved oxygen levels were too low [8] and this causes Sailfin catfish development to be rapid without competition.

Sailfin catfish is not a native Indonesian fish, it originated from the Amazon river basin, South America [9, 10]. Invasion of fish from the genus Pterygoplichthys from the family Loricariidae, its released into inland open water (river, lake, reservoir) and its growing population in tropical and subtropical freshwater bodies has serious ecological consequences [11, 12, 13]. Its population can be threatening to species other native species. Fish distribution in the Bengawan Solo river between Solo City – Sragen were dominated by Sailfin catfish [2, 14, 15]. Public perception of Sailfin catfish is generally low, except for certain species as ornamental fish, but it is better known as aquarium cleaning fish. Some people use Sailfin catfish meat, including in Sragen as a fish consumption and snack [4,16], as an alternative feed for ducks [17], the skin is very potential as a source of gelatin [18]. The protein content is 19.71 g/100 g (mg/g) [19]. Heavy metals Pb = 4.25 ppm; Cr = 0.28 ppm; Cd = 0.87 ppm; and no heavy metals Hg were found [17]. Besides Bengawan Solo river, research on Sailfin catfish has also been carried out, including research on the growth rate of Sailfin catfish in the Ciliwung river, a growth rate of 8.2 year^{-1} [20] condition factor (K) 1.125 in the Langat river Malaysia [21].

Population growth and human activities were among the main factors affecting the productivity of fish stocks in a waters. The aspects of population dynamics that support population development include growth rate, mortality rate, maximum length, length-weight relationship parameters and exploitation rate [22]. Estimation of fish stock and production potential was very important for the management of fish resources in order to remains sustainable [23]. Knowledge of fish populations was one of the bases in fish stock analysis as information in fishery resource management planning decisions. The status of inland water fish stocks in Indonesia has almost entirely decreased both in the amount of fish production and in its diversity due to overfishing and also due to decreasing water quality. Although fish resources are considered as renewable resources, their diversity can be threatened if their habitat was disturbed and will disturb fish stocks. Water pollution causes an imbalance in the aquatic biota community, including fish. One or several types of population dominate while the loss of native species that were not able to survive and cause the stock to decline. With the decreasing diversity of fish catches, an indication that stocks have decreased [24].

Based on the above problems, research on the growth of sailfin catfish in Bengawan Solo waters between Solo city and Sragen, Central Java needs to be done as input for managing fish resources of inland open waters, including the Bengawan Solo river.

2. Materials and methods
The research used a field survey method and was located in Bengawan Solo river between Solo city and Sragen Regency, Central Java Province. The sampling point was determined by purposive sampling based on the information obtained and the preliminary survey of the location where there were many Sailfin catfish. The research was conducted from May to September 2019. Sample fish were obtained by random sampling from the catch of fishermen. Samples were weighed totally and weighed per species to get the percentage composition of the catch. Sailfin catfish were taken to measure their total length with the help of an enumerator who had been trained in how to measure fish length (cm). The frequency of the length of the fish was measured every month so that the time series data for Sailfin catfish (*P. pardalis*) were obtained. Sampling length frequency was carried out at each sampling point of the research location that has been determined by filling out the length frequency form (Figure 1). Sample were obtained from various fishing gear used in these waters, especially with

gill nets of various sizes and nets. The gill nets were used with mesh sizes of 2 inches; 2¾ inches; and 3 inches; and nets with a diameter of 7 meters so that fish catches of various sizes were obtained. The method of sampling fish size was that the catch was taken randomly, then the total length of the fish was measured, which was the horizontal straight size from the tip of the snout to the end of the longest tail (cm) (Figure 2). Water quality was measured by several key water quality parameters, namely: dissolved oxygen, pH; Transparency (cm) [25].

2.1. Data Analysis

Individual fish growth parameters: The infinitive length ($L\infty$) and the growth coefficient (K) were estimated based on monthly length frequency data with the help of the ELEFAN program in the FISAT II program package [26]. The parameter of total fishing mortality (Z) was estimated using the Jones and Van Zalinge method in [22] which was based on the group basis of length and growth parameters that had been obtained. This method uses the following regression equation:

$$\text{Log } C\{(L,L_\infty)\} = a + \frac{Z}{K} \times \log(L_\infty\text{-}L) \tag{1}$$

$$\frac{Z}{K} = b \text{ (regression angle)} \tag{2}$$

Where, C (L, L_∞) is cumulative catch at length L (cm); L_∞ is infinity length; K is growth acceleration constant; and Z is the total mortality parameter. Estimation of natural mortality (M) parameters is based on [27] empirical equation:

$$\text{Log } (M) = \text{-0.0152 - 0.2790 Log } (L_\infty) + 0.6543 \text{ Log } (K) + 0.4634 \text{ Log } (T) \tag{3}$$

Where, T is average water temperature. Fishing mortality parameter (F) = Z – M and exploitation rate (E) = F/ Z. The growth of length was estimated using the Von Bertalanffy [28]:

$$L_t = L_\infty \left(1\text{-e-k}(t\text{-}t_0)\right) \tag{4}$$

Where, L_t is fish length at age t (cm), L_∞ is infinity length (cm), t_0 is the theoretical lifespan of fish at a length of 0 (cm), and K is Von Bertalanffy's growth coefficient. The theoretical age (t_0) is estimated using the Pauly empirical formula [27]:

$$\text{Log}(\text{-}t_0) = 0.3922\text{-}0.2752 \log L_\infty\text{-}1.038 \log K \tag{5}$$

Table 1. Population dynamics analysis methods [22].

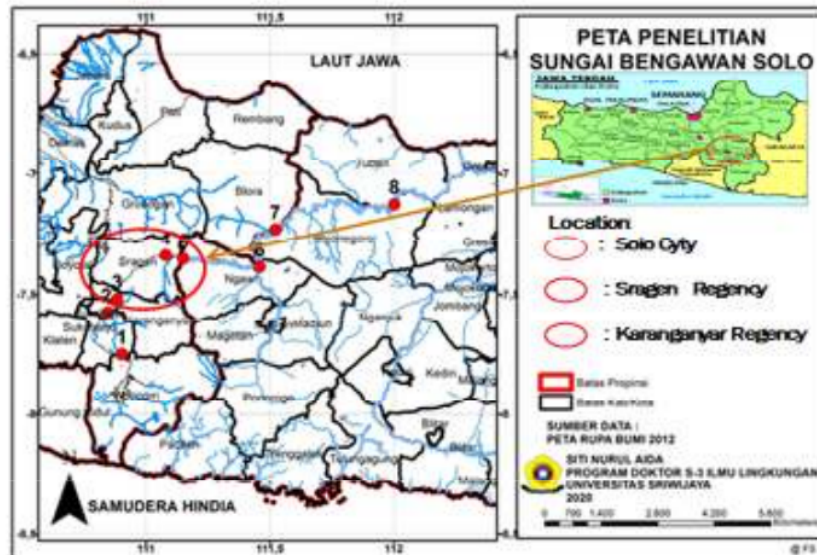| Data/Parameter	Method/Equipment	Presentation/Analysis
Growth parameters	- Lenght frequency data, time series - FISAT	- VBGF - Regression analysis
Natural mortality	- FISAT	Empiris Pauliy, D
Fishing mortality (F) dan total (Z)	- FISAT	Jones and Van Zalinge plot analysis
Exploitation rate (E)	- FISAT	Pauly, D

Figure 1. Research location in Bengawan Solo River.

Figure 2. Sailfin catfish (*Pterygoplichthys pardalis*).

3. Results and discussion
3.1. Fish Composition
Fish composition between Solo City - Sragen shows that is dominated by the Sailfin catfish species up to 90 %, this is because native fish cannot survive in polluted waters with low DO. Only Sailfin catfish can survive.
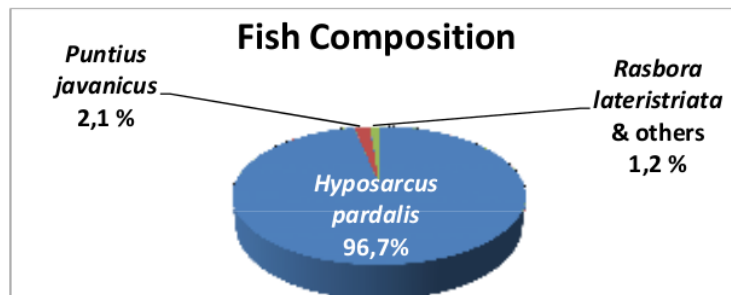

Figure 3. Composition of fish catches in the waters between Solo and Sragen.

The composition of fish catches in Bengawan Solo river between Solo and Sragen consists of 2.1% Tawes (*Barbonymus gonionotus*), other fish species such as wader fish (*Rasbora lateristriata*) and Cetul fish (Cyprinidae) by 1.2%; and Sailfin catfish (*P. pardalis*) of 96.7%. Sailfin catfish dominate the catch because they are resistant to poor water quality and very low levels of dissolved oxygen. *Pterygoplichthys* spp. also very tolerant of polluted waters [29], can easily adapt to changes in water quality [30] and easy to breed.

Meanwhile, native fish usually live in clean waters and cannot survive in polluted water conditions. Sailfin catfish can survive because they have additional respiratory organ called a labyrnth which is used when the water conditions are hypoxic or oxygen levels are very low.

3.2. Growth Parameters

Data on the catch from fishermen collected during 5 months of observation showed that the number of Sailfin catfish samples was 736 fish. Length ranges from 13-33 cm, including medium and large fish groups (Table 2). Fish size is divided into small (09.1-19.2 cm), medium (19.3-29.4 cm) and large (29.5-39.1 cm) groups. In this research, small to large sizes were found, but no fry were found because the sampling was only a few months (May to September). [7] report that in Air Hitam Riau river, Sailfin catfish were found in February ranging from = 10.2-39.1 cm; March = 09.1-33.8 cm; April = 03.8-34 cm and May = 01.8-27.8 cm.

Data on the frequency of fish length measurements in a time sequence every month are presented in Table 2. Sailfin catfish are caught every month and the peak occurs in July. Sizes 21-29 cm (medium to large) are obtained in July and August, presumably at this size the Sailfin catfish are ripe for gonads and spawned from July to August. [31] report that in the Sungai Hitam Riau, Sailfin catfish are ripe for gonads in the standard length range of 18.4–39.1mm and this size is obtained every month from February to May. The mature size of the in the Ciliwung river is larger: 373-434 mm.

Table 2. Frequency distribution of the middle length size of Sailfin catfish (*P. pardalis*) in the Bengawan Solo river.

(ML) Mid length (cm)	Jumlah Ekor				
	May	**June**	**July**	**August**	**September**
13,0	4				4
15,0	10				24
17,0	6				38
19,0	4				22
21,0	4		20		5
23,0			102		1
25,0		20	190	68	
27,0		32	140	21	1
29,0			18		
31,0					1
33,0					1

With the help of the FiSAT II program package, the growth Von Bertalanfy equation, the growth parameters (K is growth constant and L_∞ is infinitive length), natural mortality (M), capture mortality (F), total mortality (Z), and exploitation rate (E) are obtained as shown in Table 3. The result for estimation of growth parameter using length frequency data analysis, which is assisted by the FISAT program package.

Table 3. Population dynamics parameters of Sailfin catfish (*Pterygoplichthys pardalis*) in the Bengawan Solo River.

Parameter	Value
L_∞ (Asymtot length)	41.75 cm
K (Growth acceleration)	0.48
M (Natural mortality)	1.00625
Z (Total mortality)	3.573
F (Fishing mortality)	2.47
E (Rate eksploitation)	0.69

By using the highest value (R_n) of "Response Surface metfods" to project the approximate value of L_∞ and K [32] obtained L_∞ = 41.75 cm, K = 0.48 cm/year, and R_n = 0.602 (Figure 4). In the Amazon River, the infinity length of is smaller: L_∞ = 38.85 cm and growth rate K = 0.41 yr-1 [33]. In Pologolla reservoir, Sri Lanka, asymptotic total length (L_∞) = 41.3 cm and growth constant (K) = 0.3 year^{-1}. The length of the first catch from 17.8 cm to 23 cm. The length of Pterygoplichthys can reach sizes of 40 cm or more. These fish can reach a length of 35 cm in 2 years [11,30] can reach a maximum length of 49 cm [34, 35].

[36] reported that standard length frequency analysis and linear growth models supported a growth rate of around 10 cm/year. The large group was 22 cm in September 2009, developed to 27 cm in March 2010, and then to 32 cm in September 2010, thus supporting a group growth rate of about 10 cm/year. This means that the Sailfin catfish are estimated to grow to a maximum length of 41.5 cm with a growth coefficient of 0.48 year^{-1}. The maximum length that is expected to be achieved is longer when compared to the results of the research presented by [33] in Amazon River, L_∞ = 38.85 cm. The same species but live in different water locations will experience different growth, due to differences in internal and external factors that affect the growth of these fish [37]. In this case, external factors greatly affect the growth of Sailfin catfish , namely food and water conditions. Because the native fish are not able to survive, Sailfin fish population development is without competition.

The theoretical age at the time the fish length is equal to zero (t_0) is estimated by using the Pauly empirical formula [27], by inputting the values $L\infty$ = 41.75 cm and K = 0.48 year^{-1}, as follows: Log ($-t_0$) = -0.3922 - 0.2752 log (41.75) - 1.038 log (0.48), then the obtained t_0 = -0.046 years. Assuming the value of t_0 = -0.046 years, the growth curve of Sailfin catfish fish with the long growth equation of Von Bertalanffy is: $L_t = 41.75 (1- e^{-0.48 (t + 0,046)})$ can be seen in Figure 4.

$$L_t = 41,75 \ (1 - e^{-K(t-t0)})$$
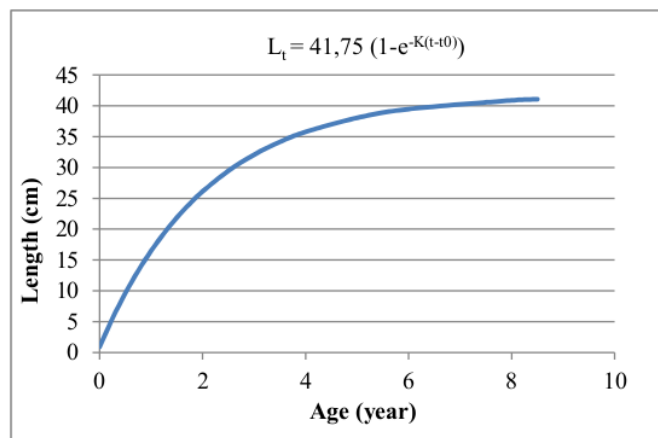
Figure 4 . Length growth of *P. pardalis* in Bengawan Solo, Central Java.

Based on the estimated growth parameters, it was found that the Sailfin catfish fish population in the waters of the Solo to Sragen regions was thought to be around two years old. [30] reported that Sailfin catfish in Texas, South America were found to be 35 cm in size with two years of age. Pterygoplichthys can reach sizes of 40 cm or more, can reach a length of 35 cm in 2 years [11,30].

3.3. Parameters of Mortality and Exploitation Rate
Estimation of natural mortality based on the results of the analysis of the length data of captured Sailfin catfish (Pterygoplichthys pardalis) following the [27] equation, natural mortality value (M) is 1.00625 and total mortality (Z) is 3.573, so estimated mortality due to fishing activities (F) is 2.56675.

By knowing fishing mortality (F) and total mortality (Z) which is analyzed based on Jones & Van Zalinge in [22] the rate of exploitation (E) can be calculated E= F/Z (E = 0.69), the value of E is greater than 0.5 that mean is over fishing.

[33]reported in Amazonas River the value of natural mortality (M) (year^{-1}) = 0.93; fishing mortality (F) (year^{-1}) = 0.91; total mortality (Z) (year^{-1}) = 1.84; length at first capture (L_c) = 21.14 cm; length at first sexual maturation (L_m) = 22.30 cm; asymptotic length (L_∞) = 38.85 cm; and growth rate (K) (year^{-1}) = 0.41; E = 0.50. Whereas in the Di Pologolla reservoir, Sri Lanka *Pterygoplichthys pardalis*, the values of Z = 0.76 years^{-1}; M = 0.73 years^{-1}; and F = 0.03 years^{-1}. The length of the first catch from the current level between 17.8 cm to 23 cm. [35] reported that asymptotic total length (L∞) is 41.3 cm and growth constant (K) 0.3 year-^{1}. Total mortality (Z) is 0.76 year^{-1}; natural mortality = 0.73 year^{-1}; and and fishing mortality is 0.03 year^{-1} respectively. Exploitation ratio from the present level of 0.4 to 0.7.

[34] said that the variation pattern of fish growth is related to the level of exploitation, environmental carrying capacity, and natural mortality (M), the recruitment that occurs every year and the number of fish that are lost from the waters. Mortality is the number of individuals lost during one time interval, natural mortality (M) and capture mortality (F). High natural mortality is found in organisms that have a large growth rate coefficient value and conversely, low natural mortality is found in organisms that have a small growth rate coefficient value. Fishery resources are natural resources that everyone can freely take these resources (open access) which are often called shared resources. Sailfin catfish can live optimally in tropical waters with a pH range of 7-7.5 and temperatures between 23-28ºC. However, these fish can still live well in poor physical and chemical conditions so that they can act as environmental indicators.

3.4. Water quality

Table 4. Water quality of Bengawan Solo – Sragen.

Parameter	Location		
	Solo City	**Solo City**	**Solo City**
GPS	S: 07° 34' 37"	S: 07° 31' 16"	S: 07° 23' 58"
	E: 110° 50 '38"	E: 110° 52' 56"	E: 110° 57' 03"
Transparency (cm)	16- 50	10-20	20- 50
pH	7.5 - 8	7.5 -8	7.5-8
DO (mg/L)	1.7-3.4	0.41 – 2.43	0.98 – 3.61

Based on Table 4, it is known that environmental conditions will affect water quality, then water quality will affect aquatic life, especially fish. The parameter which is often the limiting factor for fish life is dissolved oxygen. Dissolved oxygen levels are related to the degree of water acidity (pH) and the level of brightness. The brightness level ranges from 10-50 cm, which means that the brightness is very low due to pollution that is happening in the waters. This indicates pollution by organic waste in the process of becoming glucose [38] and into methane and carbon dioxide [39]. The process of decomposing organic acids began to occur after more than 2 days [38, 40].

Based on visual observations and several analyzes of water quality in situ, the Bengawan Solo river in the Solo Sragen area has been polluted. Dissolved oxygen content in the studied area of Bengawan Solo ranged from 1.7 to 3.4 mg/L. At Karanganyar station, dissolved oxygen Sragen has very low dissolved oxygen values ranging from 0.8 to 1.0 mg / L. At this location the catch of fish is dominated by Sailfin catfish. Based on the water quality standard [41] for temperatures ranging from 20-32°C, the condition of Bengawan Solo waters in terms of temperature parameters is good enough to support fish life. Meanwhile, the water transparency and DO levels did not meet the water quality standards, where the brightness was > 45 cm. The DO value of this research result is the same as the research result of [2] in Bengawan Solo, which stated that the value of O2 in Cemeng and Bak Kramat/Karanganyar Villages was recorded at 0 mg/L. Based on three key water quality parameters for fish life, the Solo, Karanganyar location has very poor and dirty water quality.

4. Conclusion
Although the water quality of Solo River between Solo City - Sragen districts is poor, Sailfin catfish is able to grow well and the natural mortality is low. The composition of fish species in Solo River between Solo City - Sragen districts are dominated by Sailfin catfish.

5. Acknowledgments

5. References
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