Some population parameters of the common carp (Cyprinus carpio, 1758) in Lake Paniai, Papua

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Abstract. Common carp (Cyprinus carpio) is known as introduced fish on some lakes in Indonesia and included in herbivore fish. The common carp population in Lake is the dominant number, so that it’s become at of fishing target. Estimation of some parameters of common carp population in Lake Paniai was aimed to evaluate the growth parameters, mortality, the fishing rate and recruitment pattern. Collecting and measuring the fish sample was done in the period from February to October 2016 by using the fishing gear of gill nets with mesh sizes of 1.00 - 4.50 inches. The results showed that common carp population in Lake Paniai was dominated by individual lengths between 15-25 cm with a frequency of 55.78%, the growth pattern of male fish was allometric (-) and females were isometric. Asymptotic length (L∞) = 61.43 cm and the growth coefficient (K) = 0.32 per year. The rate of natural mortality (M) = 0.65 per year, the fishing mortality rate (F) = 0.52 per year, the total mortality rate (Z) = 1.17 per year and the exploitation rate (E) = 0.44. The exploitation rate of common carp fish was still below the optimum value, thus an attempt to catch this fish, could be still improved. Common carp populations caught by mostly fishermen have had a chance to spawning thus common carp fish population in the lake was estimated to still be preserved and could be utilized in a sustainably. Peak recruitment occurred only once in a year, namely in June.

Keywords: common carp fish; Lake Paniai; population parameters; Papua

1. Introduction

Common carp (Cyprinus carpio) is a type of fish often caught by gill nets in Lake Paniai together with Nile tilapia, it is included in the group of herbivore fish because its main food is phytoplankton [1]. In the taxonomy, the fish included: subfamily Cyprininae, family Cyprinidae and the order of Cypriniformes [2]. Common carp and tilapia in Lake Paniai are an introduced fish (Personal communication) and these fish are able to adapt and proliferate.

In the catch composition of gill nets, fish populations of common carp, tilapia and crayfish of Cherax were dominant with the order of dominance: tilapia, common carp and crayfish. Common carp can live and breed in inland waters such as rivers, reservoirs and lakes [1, 3]. Aquatic habitat characteristics preferred by this fish species are waters with depths ranging between 10-15 meters, pH between 7.0-7.5 and water temperature between 33-35°C. Common carp stocking program in Lake Paniai conducted by the District Government is intended to help local fishermen to sustainability in fishing as a livelihood due to native fish catches in the waters of the lake have not reliable anymore.

Lake Paniai is located at the western end of the cordilleran in the hollow interior of Papua highlands. Administratively, Lake Paniai is Entered in the territory of the East Paniai District Area, Paniai
Regency, Papua Province and an altitude of ± 1700 meters above sea level, the depth of ± 50 meters with the lake surface area of ±14,500 ha [4]. Various types of freshwater fish and shrimp found in Lake Paniai, but fish populations of common carp (Cyprinus carpio), Tilapia (Oreochromis niloticus) and Cherax crayfish (Cherax sp.) are the dominant aquatic animals in this lake.

The common carp has been one of the dominant populations caught in Lake Paniai, it is needed for proper management so that the resources of this fish population can be used optimally and sustainably. The research objective was to determine some parameters of the common carp population (growth, mortality, the exploitation rate and recruitment pattern) in Lake Paniai as important information for the management of this fish resource.

2. Material and methods

Fish sampling was done by placing the fishing gear of gillnets on 4 areas (figure 1), namely: a) Areas of inlet and near settlements (stations 1 and 2), b) around the middle of the lake (stations 3, 4 and 5), c) area close to the crop estate (station 6), and d) the outlet area (station 7).

Data for analysis the length-weight relationship of fish used data derived from the catches by measuring the length and weight of fish at each time of survey. Surveys were conducted 4 times, on February, April, July and October 2016. For the analysis of the growth parameters, mortality, the fishing rate and recruitment patterns, used the data from the catch of fishermen at five locations by means of measuring the length of each individual fish (length frequency) conducted by enumerators every month starting from March to October 2016.

The fishing gear of gillnets used had mesh size of 1.00 to 4.50 inches (1.00; 1.50; 1.75; 2.00; 2.25; 2.50; 3.00; 3.50; 4.00 and 4.50 inches). The total length of fish was measured by using a measuring board to the nearest 0.1 cm and weighs was weighed to the accuracy of 1 gram each individual fish. Length and weight data were used for further analysis to obtain the growth pattern, is it to be isometric (b = 3) or allometric (b ≠ 3). Functional equations used in the analysis of a length and weight relationship was the formula proposed by Effendie [5], namely:

\[ W = a^t L^b \]  

Where: \( W \) = weight of fish (g), \( L \) = total length (cm), a and b values = constants.

The constant value b of the equation \( W = a^t L^b \), was tested for accuracy against the value of b = 3 by using \( t_{\text{test}} \) at a confidence level of 95% [6-8]. If the test results were not different from the constant value b with 3, the growth pattern of fish was isometric, and vice versa when the test results of b value different with 3, the fish had to be allometric growth pattern.

Estimates of growth parameters following the Von Bertalanffy growth model [8]:

\[ L_t = L_\infty \times (1 - \exp(-k \times (t - t_0))) \]  

where \( L_t \) = length of the fish at age \( t \), \( L_\infty \) = asymptotic length (maximum length of the average), \( K \) = coefficient of growth and \( t_0 \) = theoretical age at length 0 cm. Asymptotic length (\( L_\infty \)) and growth coefficient (K) was calculated by using the ELEFAN I in the computer program package FISAT II [9]. The estimation of the value of \( t_0 \) was calculated based on Pauly [10].

\[ \log (-t_0) = -0.3922 - 0.2752 \log (L_\infty) - 1.038 \log (K) \]  

The rate of natural mortality (M) was estimated using empirical models Pauly [11]:

\[ \log (M) = -0.0066 - 0.279 \log (L_\infty) + 0.6543 \log (K) + 0.4634 \log (T) \]  

where, \( L_\infty \) = asymptotic length, \( K \) = growth coefficient and \( T \) = the average temperature of the waters of Lake Paniai (24°C). The total mortality rate (Z) was analyzed using length converted catch curve [10]. Its estimate used the program package FISAT II [9]. The rate of fishing mortality (F) was calculated from the equation:

\[ F = Z - M \]
and the exploitation rate (E) was calculated using an equation proposed by Pauly [11], namely:

\[ E = \frac{F}{Z} \]  

Estimation of the average length caught done by plotting the relationship between fish length (X-axis) with the number of fish (Y axis) in order to obtain the curve shape of the letter S.

The value of length at first capture length at 50% first caught was calculated by the following equation [8]:

\[ SL_{-est} = \frac{1}{1 + \exp (S1 - S2 \times L)} \]  
\[ \ln \left[ \frac{1}{SL} - 1 \right] = S1 - S2 \times L \]  
\[ L_{50\%} = \frac{S1}{S2} \]

where SL = logistic curve; S1 and S2 = constants on formula of logistic curve

Figure 1. Sampling location of common carp fish in Lake Paniai.

Legends:  
1. St. Ibumu Maeda  S.03°52’56.2”  E.136°21’38.6” 
2. St. Kali Aga     S.03°54’52.7”  E.136°22’26.4” 
3. St. Alami        S.03°51’54.2”  E.136°19’09.2” 
4. St. Obano        S.03°53’58.4”  E.136°16’33.9” 
5. St. Pulau Kambing S.03°54’24.9”  E.136°17’58.2” 
6. St. Muara Dimea  S.03°56’09.3”  E.136°18’37.1” 
7. St. Outlet (Kali Awe) S.03°56’32.3”  E.136°21’47.0”
3. Results and discussion

3.1. Results
Common carp, *Cyprinus carpio*, which was caught by fisherman in Lake Paniai (figure 2) had a characteristic golden yellow color with black spots on the back and white on the abdomen. There were 36 scales in the lateral line which is in the range of 36-37, hard spines of dorsal fin there were 3 soft thorns totaled 17. Two hard and five soft spines on the anal fin. In the taxonomy, common carp is included in the subfamily Cyprininae, family Cyprinidae and the order Cypriniformes [2]. This fish species in Lake Paniai included the herbivore fish because the main food was phytoplankton [1].

Results of the length-weight relationship analysis as shown in figure 3, for male common carp (3a) followed the functional equation of \( W = 0.0213L^{2.8154} \) with regression coefficient of \( R^2 = 0.9446 \). The \( t \) test results on the parameter \( b \) with a level of 95% got the value of \( t_{\text{count}} = 2.181 \) was bigger than \( t_{\text{table}} = 1.671 \), thus the value of the parameter \( b \) was different from 3 (\( b \neq 3 \)) which showed the growth pattern was allometric (-). Length-weight relationship of the female fish (3b) followed the functional equation of \( W = 0.013L^{3.0068} \) with regression coefficient of \( R^2 = 0.9734 \). The \( t \) test results on the parameter \( b \) with a level of 95% got the value \( t_{\text{count}} = 0.136 \) was smaller than \( t_{\text{table}} = 1.658 \), thus the value of the parameter \( b \) was not different from 3 (\( b = 3 \)) indicating that growth was isometric pattern.

![Figure 2. The common carp (*Cyprinus carpio*) from Lake Paniai.](image)

![Figure 3. Length-weight relationship curve of common carp in Lake Paniai: (a) male and (b) female.](image)
Length frequency data measured from March to October 2016 (table 1), showed that the common carp population in Lake Paniai was dominated by 15-25 cm length with a frequency of 55.78% (figure 4).

**Table 1.** Length frequency data of common carp (*Cyprinus carpio*).

| No | Mid Length | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Σ   |
|----|------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1  | 10.5       | 1   | 3   |     |     |     |     |     |     | 4   |
| 2  | 11.5       | 4   | 2   |     |     |     |     |     |     | 6   |
| 3  | 12.5       | 1   | 2   |     |     |     |     |     |     | 3   |
| 4  | 13.5       | 9   | 2   | 5   | 4   |     |     |     |     | 20  |
| 5  | 14.5       | 21  | 11  | 15  | 12  |     |     |     |     | 59  |
| 6  | 15.5       | 11  | 11  | 15  | 4   |     |     |     |     | 41  |
| 7  | 16.5       | 29  | 13  | 28  | 14  | 9   |     |     |     | 93  |
| 8  | 17.5       | 32  | 20  | 31  | 10  | 12  |     |     |     | 105 |
| 9  | 18.5       | 26  | 14  | 17  | 14  | 8   | 2   |     |     | 81  |
| 10 | 19.5       | 28  | 14  | 32  | 6   | 11  | 3   |     |     | 94  |
| 11 | 20.5       | 31  | 14  | 21  | 8   | 7   | 3   | 2   |     | 86  |
| 12 | 21.5       | 12  | 6   | 10  | 3   | 10  | 5   | 3   | 7   | 56  |
| 13 | 22.5       | 3   | 8   | 5   | 2   | 11  | 7   | 3   | 6   | 45  |
| 14 | 23.5       | 11  | 7   | 18  | 11  | 13  | 14  | 12  | 12  | 98  |
| 15 | 24.5       | 3   | 2   | 3   | 4   | 9   | 11  | 9   | 12  | 53  |
| 16 | 25.5       | 5   | 3   | 3   | 8   | 5   | 11  | 10  | 9   | 54  |
| 17 | 26.5       | 7   | 1   | 4   | 5   | 6   | 9   | 15  | 11  | 58  |
| 18 | 27.5       | 5   | 7   | 6   | 11  | 8   | 10  | 9   | 13  | 69  |
| 19 | 28.5       | 3   | 2   | 2   | 8   | 5   | 7   | 5   | 9   | 41  |
| 20 | 29.5       | 3   | 10  | 14  | 10  | 4   | 6   | 5   | 9   | 61  |
| 21 | 30.5       | 5   | 8   | 16  | 8   | 3   | 4   | 12  | 11  | 67  |
| 22 | 31.5       | 2   | 1   | 2   | 3   | 6   | 7   | 8   | 29  |     |
| 23 | 32.5       | 2   |     |     | 4   | 8   | 9   | 5   | 28  |     |
| 24 | 33.5       |     |     |     | 2   | 2   | 3   | 6   | 13  |     |
| 25 | 34.5       |     |     |     | 3   | 5   | 1   | 3   | 12  |     |
| 26 | 35.5       |     |     |     | 1   | 1   | 1   | 2   | 5   |     |
| 27 | 36.5       |     |     |     | 2   | 1   | 4   | 1   | 8   |     |
| 28 | 37.5       |     |     |     | 1   | 0   | 0   | 1   | 2   |     |
| 29 | 38.5       |     |     |     | 1   | 3   | 0   | 0   | 4   |     |
| 30 | 39.5       |     |     |     | 3   | 1   | 2   | 0   | 6   |     |
| 31 | 40.5       |     |     |     | 0   | 0   | 1   | 6   | 7   |     |
| 32 | 41.5       |     |     |     | 0   | 0   | 1   | 1   | 2   |     |
| 33 | 42.5       |     |     |     | 2   | 0   | 1   | 1   | 4   |     |
| 34 | 43.5       |     |     |     | 1   | 1   | 1   | 1   | 4   |     |
| 35 | 44.5       |     |     |     | 1   | 2   | 2   | 1   | 6   |     |
| 36 | 45.5       |     |     |     | 1   | 1   | 2   | 0   | 4   |     |
| 37 | 46.5       |     |     |     | 1   | 0   | 2   | 2   | 5   |     |
| 38 | 47.5       |     |     |     | 0   | 1   | 1   | 2   |     |     |
| 39 | 48.5       |     |     |     | 1   | 1   | 1   | 3   |     |     |
| 40 | 49.5       |     |     |     | 1   | 1   | 0   | 2   |     |     |
| 41 | 50.5       |     |     |     | 1   | 1   | 0   | 2   |     |     |
| 42 | 51.5       |     |     |     | 1   | 1   | 0   | 1   |     |     |
| 43 | 52.5       |     |     |     | 1   | 1   | 2   |     |     |     |
| 44 | 53.5       |     |     |     |     |     |     |     |     |     |
| 45 | 54.5       |     |     |     |     |     |     |     |     |     |
| 46 | 55.5       |     |     |     |     |     |     |     |     |     |
| 47 | 56.5       |     |     |     |     |     |     |     |     |     |
| 48 | 57.5       |     |     |     |     |     |     |     |     |     |
| 49 | 58.5       |     |     |     |     |     |     |     |     |     |

|     | 254 | 154 | 252 | 144 | 147 | 126 | 128 | 143 | 1348 |

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Analyzing the results of length frequency distribution by using packet FISAT II program obtained the fish growth model of common carp (*Cyprinus carpio*) in Lake Paniai followed the von Bertalanffy equation namely: 

\[ L_t = 61.43 \times (1 - \exp(-0.32 \times (t - (-0.43)))) \]  

or 

\[ L_t = 61.43 \times (1 - \exp(-0.32 \times (t + 0.43))) \]  

(figure 5).

Based on the growth parameter values of fish above, obtained a constant value of natural mortality (M) of 0.65 per year and total mortality (Z) with the analysis using the model of length converted catch curve (figure 6), obtained a value of 

\[ Z = 1.17 \]

Fishing mortality (F) existed for \( Z - M \) was 

\[ F = 0.52 \]  

per year and the exploitation rate of fish populations (E) was 

\[ E = \frac{F}{Z} \]  

there by \( 0.44 \). Based on the value of \( E = 0.44 \), meaning the exploitation rate of this fish in Lake Paniai was still below the optimum value, meaning the catches of common carp fish in Lake Paniai had not exceeded the optimal value. Thus, fishing activities for species of fish in Lake Paniai can still be improved. All parameter values of the fish populations in Lake Paniai obtained from the analysis were listed in table 2.

![Figure 4](image1.png)

**Figure 4.** Length frequency distribution of common carp fish in Lake Paniai.

![Figure 5](image2.png)

**Figure 5.** Growth curve of common carp fish in Lake Paniai.
Table 2. Population parameter values of common carp fish in Lake Paniai, Papua.

| No | Parameters                          | Symbols | Values     |
|----|------------------------------------|---------|------------|
| 1  | Asymptotic length                  | $L_\infty$ | 61.43 cm  |
| 2  | Growth Coefficient                 | $K$     | 0.32/year  |
| 3  | Theoretical age at $L_t = 0$ cm    | $t_0$   | -0.43 year |
| 4  | Natural Mortality                  | $M$     | 0.65/year  |
| 5  | Fishing Mortality                  | $F$     | 0.52/year  |
| 6  | Total Mortality                    | $Z$     | 1.17/year  |
| 7  | Exploitation rate                  | $E$     | 0.44/year  |
| 8  | Average first length caught        | $L_c$   | 22.25 cm   |

The average size of the fish length (*Cyprinus carpio*) caught on the 50% probability level ($L_c$) of the research was 22.25 cm TL (figure 7). Functional equation of the logistic curve was: $SL_{est} = 1/(1+exp(S1-S2*L)) = 1/(1+exp (11.018 - 0.4953 * L))$.

Based on figure 8, the recruitment patterns of fish in Lake Paniai happened only once in a year, namely in June (15.83%), thus recruitment or peak spawning season of common carp fish in the lake occurred in June.

![Figure 6](image1.png)

**Figure 6.** Total mortality ($Z$) of the common carp population by using the length converted catch curve model.

![Figure 7](image2.png)

**Figure 7.** Mean length of common carp (*Cyprinus carpio*) caught in Lake Paniai, Papua.

![Figure 8](image3.png)

**Figure 8.** Recruitment pattern of common carp (*Cyprinus carpio*) in Lake Paniai.
3.2. Discussion
Growth patterns of the male common carp was negative allometric, its meant that the growth of length was faster than the growth of weight indicating the condition of the male common carp fish population in Lake Paniai was thin condition (not fat). With the growth pattern of allometric negative indicated that the growth of male fish in the lake was classified as less than ideal. For female common carp fish, the growth pattern was an isometric, which meant the growth of length was balanced or equivalent with the growth of weight that indicated the condition of the female fish population in Lake Paniai was quite ideal (not thin and not fat). The growth pattern of a fish species in the waters to identify the magnitude of the parameter value of $b$ can be influenced by the development of gonad maturity level, gender, age, geographical position, environmental conditions and season [12]. The growth of fish can be influenced by environmental factors such as: the type and size of the food, the size of the fish, environmental quality, and condition of the fish (age, genetics and heredity) [13]. Length-weight relationship of female common carp fish with the parameter value of $b$ was equivalent to 3 (isometric) indicated that the growth pattern of the female fish populations in Lake Paniai included well either.

The growth curve showed the fish population can grow up to the size of the average maximum length ($L_{\infty}$) = 61.43 cm with growing speed/growth coefficient ($K$) of 0.32 per year. If a fish with a growth coefficient of less than 1 ($K <1$) the growth rate of the fish species was slow [14]. As comparison of the range and magnitude of the $K$ value for common carp fish species that live naturally in the waters of rivers, lakes and reservoirs can be seen in table 3 [3].

| No | Habitats    | N  | Range Values of $K$ | Mean and std of $K$ |
|----|-------------|----|---------------------|---------------------|
| 1  | Rivers      | 16 | 0.06 - 0.48         | 0.27 ± 0.11         |
| 2  | Lakes       | 20 | 0.12 - 0.75         | 0.34 ± 0.21         |
| 3  | Reservoirs  | 14 | 0.11 - 0.69         | 0.29 ± 0.17         |

Sources: FishBase [3].

The range and average growth coefficient ($K$) as showed in table 3, common carp fish populations naturally living in the lake have a faster growth than when the fish live in the rivers and reservoirs (Fish Base, 2011). The growth coefficient ($K$) value of common carp fish populations that live in Lake Paniai ($K = 0.32$ per year) into the range of the $K$ value of the common carp fish populations that live naturally in most waters of Lake ($K = 0.12$ to 0.75) (table 3), thus rated $K$ for common carp fish populations living in Lake Paniai included quite good because almost equal to the average $K$ value for the common carp fish populations that live in the waters of other lakes. If the growth coefficient ($K$) value of a fish species was low, it indicated the growth rate of fish to reach the average maximum length was also low, then fish with small growth coefficient ($K$) would have a longer life cycle [15]. Amir et al. [16] and Djumanto and Setyobudi [17] also expressed the same growth rate of the same fish species and lived-in different waters more due to the similarity of water characteristics of the ecological conditions of the aquatic habitat from time to time. By given the growth coefficient ($K$) value of 0.32 on the common carp fish species in Lake Paniai, the water characteristic of Lake Paniai have much in common with other lake water characteristics in terms of available food adequacy and suitable water conditions as living habitat for common carp fish populations [18].

Based on the fishing mortality ($F$) value of 0.52 which was smaller than natural mortality ($M$) value of 0.65 indicated fishing pressure on common carp fish populations with exploitation rate ($E$) value of 0.44 was still below its optimum value. The rated $E$ of fish populations that are lower than the optimum value, indicating the stock of fish in waters classified as not abundant, so that increasing the efforts to catch from year to year should be still restricted and optimized [19]. In relation to the research, fishing efforts in Lake Paniai could be increased to close to an optimum value ($E_{opt} = 0.5$) because the $E$'s Common carp fish of 0.44 was smaller than an optimum value. The exploitation rate
(E) of a fish stock is at its maximum level and sustainable if the value of F was equivalent with or same with the value of M or the rate of exploitation (E) had value of 0.5 [20].

The results of analysis of the smallest mid length were 10.5 cm, the largest of 58.5 cm and the size of the average first length captured (Lc) = 22.25 cm. First gonad maturity size (Lm) was 16.12 cm [1]. In the book of the utilization status of fish resources in the Java Sea waters, some researchers said, if the population of a fish species had a value of the average length caught (Lc) was smaller than the size of the average length of the first gonad maturity, it indicated that mostly fish which were caught had not time to do a spawning [21-23]. From these statements and in accordance with the results of this study, the size of the average first length caught (Lc) value was greater than the size of the average length of the first gonad maturity (Lm), so that it can be concluded that the common carp fish populations caught by fishermen on Lake Paniai largely had time to do the spawning process before being caught.

4. Conclusion
Common carp fish populations in Lake Paniai were dominated by individuals measuring 15-25 cm (TL) with a frequency of 55.78%. Length-weight relationship of the male fish were negative allometric with a functional equation of $W = 0.0213L^{2.8154}$ and isometric for the length-weight relationship of the females with the functional equation of $W = 0.013L^{3.0068}$. Asymptotic length (L∞) = 61.43 cm and the growth coefficient (K) = 0.32 per year. The rate of natural mortality (M) = 0.65 per year, the rate of fishing mortality (F) = 0.52 per year, the total mortality rate (Z) = 1.17 per year and the rate of exploitation (E) = 0.44. The value of exploitation rate was under optimum value so that the fishing effort for the common carp fish in Lake Paniai could still be improved. The common carp fish population caught by fishermen mostly have had time to do spawning, thus the fish population in the lake was expected to remain sustainable and can be utilized in a sustainable manner. Peak spawning season with diagram of recruitment pattern was expected to occur in June

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