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Research Article

Morphoregression and Reproduction Aspect of Bonylip Barb (*Osteochilus vitattus* Valenciennes, 1842) in Tamblingan Lake, Bali Island

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Abstract

Bonylip barb (*Osteochilus vitattus* Valenciennes, 1842) is one of many native fish inhabiting Tamblingan Lake. The information about this species in Tamblingan Lake is rare which requires fulfilment in information gaps for the management of bonylip barb. The aims of this research were to find out the length-length relationship, length-weight relationship, length at first maturity, sex ratio, gonadal maturity stage, gonadosomatic index (GSI), fecundity, as well as spawning period and location in Tamblingan Lake. The fish sample was captured with experimental gillnet that was set in the afternoon and hauled in the next morning. Length and weight of every sample were taken. All samples were dissected to observe the sex and gonad. Fork length was the type of length with higher accuracy to estimate the body weight than the other length character. Growth pattern of this species was isometric. Lm_{50} of bonylip barb in Tamblingan Lake was 116 mmTL. Sex ratio of bonylip barb was imbalanced (1.00:0.82). Gonad maturity stage I-V was found during the research with GSI between 0.16-15.50 for male fish and 0.43-32.82 for female fish. The highest GSI was found in March, 15.50 for male fish and 32.73 for female fish. Mature fish were discovered in all stations in every month of sampling. The fecundity of bonylip barb ranged between 2,792-279,326 eggs. The length-length and the length-weight showed a strong relationship. The fish was isometric. Based on the growth pattern and the reproductive aspects, the population of bonylip barb in Tamblingan Lake was in good condition.

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1. Introduction

Bonylip barb (*Osteochilus vitattus* Valenciennes, 1842) is one of many native fish inhabiting Tamblingan Lake. The presence of this species in freshwater ecosystem in Indonesia is distributed across Sumatera Island (Uslichah and Syandri, 2003; Zulfahmi *et al*., 2021), Java (Hedianto *et al*., 2013; Sriwidodo *et al*., 2013), Borneo (Santoso and Wahyudewantoro, 2019), Celebes (Herjayanto *et al*., 2019), and Bali (Taradhipa *et al*., 2018; Pertami *et al*., 2020). Bonylip barb has the potential to be a superior aquaculture commodity (Jubaedah and Hermawan, 2010) that reaches the export market (Muchlisin, 2013; Syandri *et al*., 2014). In ecological function, bonylip barb is planktivorous and detritivorous that which can act as a biological agent to control eutrophication (Syandri, 2004).

The research about bonylip barb had been conducted on other ecosystem and in laboratory-scale. Some research related to this species in other freshwater ecosystem have discussed about the growth pattern and condition (Jusmaldi *et al*., 2020a), reproduction aspect (Omar, 2010), growth and reproduction aspect (Rochmatin *et al*., 2014), genetic variation (Azrita *et al*., 2014) and fecundity (Syandri *et al*., 2015; Rostika *et al*., 2017). There were also some research in laboratory-scale about induced spawning (Muchlisin *et al*., 2014; Adami *et al*., 2016), gonadal maturation (Setyaningrum *et al*., 2017; Habibah *et al*., 2020), eggs quality (Tarigan *et al*., 2020), and post larva development (Yusuf *et al*., 2014). Although research of bolylip barb has been published in many locations and aspects, research about this fish in the freshwater ecosystem in Bali is still rare and the information of bonylip barb from this location is original. The information related to bonylip barb is only about growth parameter (Sravishta *et al*., 2018) and parasite prevalence in Buyan Lake (Sitompul *et al*., 2019) and length distribution in Tamblingan Lake (Pertami *et al*., 2020).

Based on rare information about bonylip barb in Tamblingan Lake, it is important to conduct the morphoregression and reproductive aspects research of this species as a source of initial information or management bonylip barb. The information is very crucial and a basic requirement to plan better management strategies of fishery resources to the domestication of bonylip barb population in Tamblingan Lake by aquaculture base (Muchlisin *et al*., 2010; Muchlisin, 2014).

The aims of this research were to find out the morphoregresion and reproduction aspect of bonylip barb that comprise length-length relationship, length-weight relationship, growth pattern, length at first maturity, sex ratio, gonadal maturity stage, gonadosomatic index (GSI), fecundity, as well as spawning time and location in Tamblingan Lake.

2. Material and Method

2.1 Period and Location of Study

Sampling was done between January-December 2019 in Tamblingan Lake (Figure 1). This lake is located at 1,217 meters above sea level with an area around 190 ha and the depth around 70-80 m. The fish sampling was carried out with *purposive sampling* technique at five stations where each has contrasting ecological characters representing the conditions of Tamblingan Lake (Table 1).

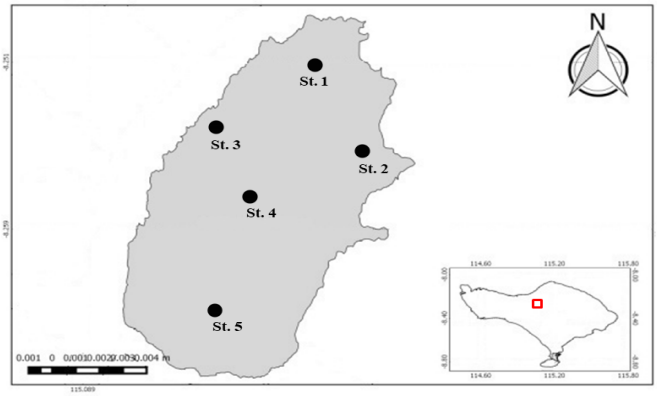

Figure 1. Sampling station in Tamblingan Lake during January-December 2019

2.2 Sampling Method

The fish sample were captured by gillnet with a width of 300 m and a height of 2 m and a mesh size of 0.5; 1.0; 1.5; 2.0; 2.5; 3.0 cm. The gillnet was set in the afternoon (05.00 PM) and hauled in the morning (at 08.00 AM) in the next day. Fish sample was separated based on sampling station and then preserved with 10% formaldehyde. The sample was carried to Fishery Laboratory, Facczzczcvulty of Marine Sciences and Fisheries, Udayana University.

Length of fish was measured using centigrade scale with an accuracy of 0.1 cm and the weight of fish was measured using a digital scale with 0.01 g accuracy. All fish samples were dissected to observe

Table 1. Station name, coordinate, and ecological characteristic of each bonylip barb in Tamblingan Lake during January-December 2019

No.	Name station	Coordinate	Ecological characteristic
1	Lenggang	S : 08º 25' 307" E : 115º 10' 193"	Higher coverage of aquatic plants (*Nymphoides* sp.), the topography was rather steep and rocky.
2	Pura Dalem	S : 08º 25' 657" E : 115º 10' 212"	A rocky lake littoral zone, aquatic plants (*Cyperus* spp.), fishing area, and holy area for Hindu religion.
3	Tirta Mengening	S : 08º 24' 987" E : 115º 09' 732"	Cliff littoral zone, found dead tree trunks, and holy area for Hindu religion.
4	Tengah	S : 08º 26' 281" E : 115º 09' 787"	Location for the fishers to spread their nets, the water current is quite strong, and the deepest zone of Tamblingan Lake.
5	Pos Nelayan	S : 08º 26' 524" E : 115º 09' 441"	Higher coverage of aquatic plants (*Nymphoides* sp.), a sloping littoral zone, a location for the fishermen to catch fish by spearfishing.

the sex and gonad maturity stage. The gonad sample was weighed using a digital centigrade scale with an accuracy of 0.0001 g.

Fish fecundity was calculated using gravimetric method. The mature ovaries (stage III and IV) were divided into three parts: anterior, middle, and posterior. Each part was considered as a sub-gonad. The spawning period and spawning location of bonylip barb were determined based on the presence of mature fish in every sampling period and sampling location during this research.

2.3 Data Analysis

Length-length relationships (SL-FL, SL-TL, FL-TL) were analyzed through linear regression. All length parameters were to be correlated against weight. The length-weight relationship was determined using the equation:

$$W = aL^b$$

where:
W: weight (g); a and b: regression constant (intercept and slope) of length-weight; L: length of fish (mm).

The value of slope (b) formed on this equation was then tested using the t test on 95% confidence interval, using Microsoft Excel. The condition of H0 is where b = 3, indicating isometric growth pattern, whereas the condition of H1 is where b≠3, indicating allometric growth pattern.

Size at maturity is defined as the size at which 50% of the individuals in the sample size are in the mature stage. This was determined by using a logistic model by fitting the fraction of mature fish against length intervals using the nonlinear least square regression method (King, 2007)

The sex ratio was analyzed by comparing the number of male fish with female fish. The equation used is as follows (Jega *et al*., 2017):

$$Sr = \frac{M}{F}$$

where :
Sr: Sex ratio; M: number of male fish; F: number of female fish

To determine the balance of the sexes, where hypothesis H_0 is balanced and H_1 is unbalanced, with $p<0.05$, the chi square test was used using the equation:

$$X^2 = \sum \frac{(o_i - e_i)^2}{e_i}$$

where :
o_i: observed frequency of male and female; e_i: expected frequency of male and female in balanced sex ratio condition

Gonadosomatic Index (GSI) calculated by following equation (Khelifi *et al*., 2019):

$$GSI = \frac{WG}{W} X\ 100$$

where :
GSI: gonadosomatic index; WG: gonad weight; W: fish weight

Fecundity was calculated by gravimetric method by following equation (Hasan *et al*., 2020):

$$F = \frac{G}{Q} X\ N$$

where :
F: fecundity (grain); G: gonad weight (g); Q: sub gonad weight (g); N: total of egg in sub gonad (grain)

3. Results and Discussion

3.1 Results

The total sample of bonylip barb during the study was 454 fish. The range of total length, forklength, and standard length were 90-211 mmTL, 80-177 mmFL, and 60-168 mmSL. The length-length relationship of bonylip barb in Tamblingan Lake had a high value of coefficient of determination (Figure 2). Total length, fork length, and standard length were reliable to estimate the fish body weight with $R^2 > 0.88$ (Figure 3). Based on the b value, the growth pattern of this species was isometric (b=3). The length at first maturity (Lm_{50}) of bonylip barb in Tamblingan Lake was 116 mm TL (Figure 4). Most of the bonylip barb in this study were mature fish that had passed the Lm_{50} size.

The fish consisted of 247 males, 202 females, and 5 unidentified. Male bonylip barb was found more than female ones. Female bonylip barb was not found in January. The sex ratio between males and females bonylip barb in Tamblingan Lake was 1.00:0.82 and the sex ratio of the mature fish was 1.00:0.84 (Figure 5). Based on the chi-square test ($p<0.05$), it was detected that the ratio of males and females was imbalanced.

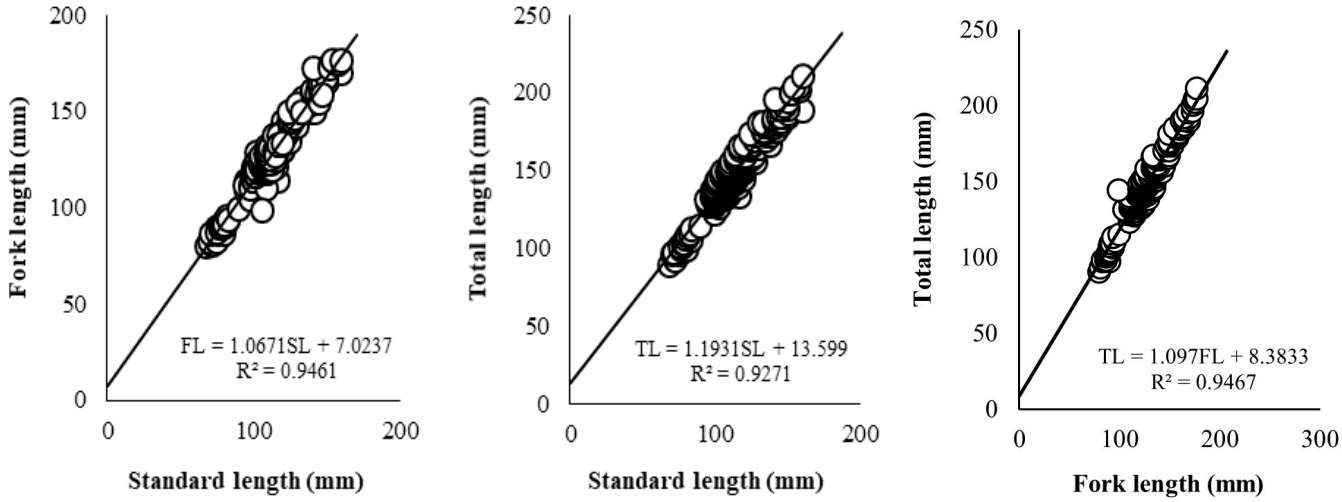

Figure 2. Length-length relationship of bonylip barb in Tamblingan Lake during January-December 2019

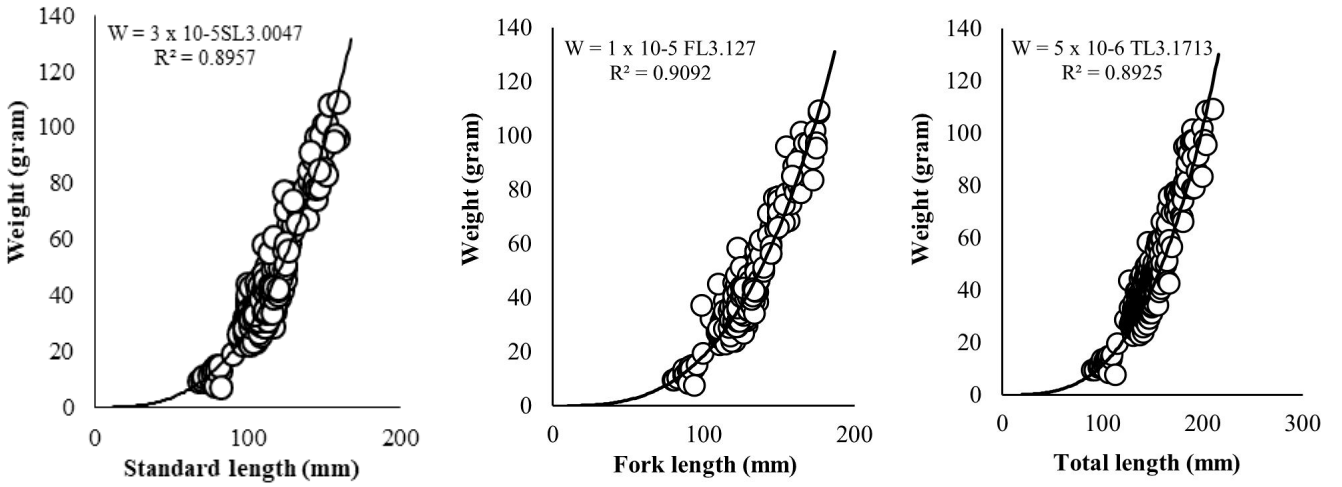

Figure 3. Length-weight relationship of bonylip barb in Tamblingan Lake during January-December 2019

The Gonad Maturity Stage (GMS) of the male fish was at GMS I, II, III, and IV, while female fish at GMS II, III, IV, and V. The proportion of mature bonylip barb (stage III and IV) was higher than the immature ones (Figure 6 and Figure 7). Immature bonylip barb count was minimal. Most of the fish were mature. There were 421 mature fish (229 male and 192 female) and only 19 immature fish (18 male and 1 female). There were five female fish found in after spawning condition. The mature bonylip barb were found every month during the study.

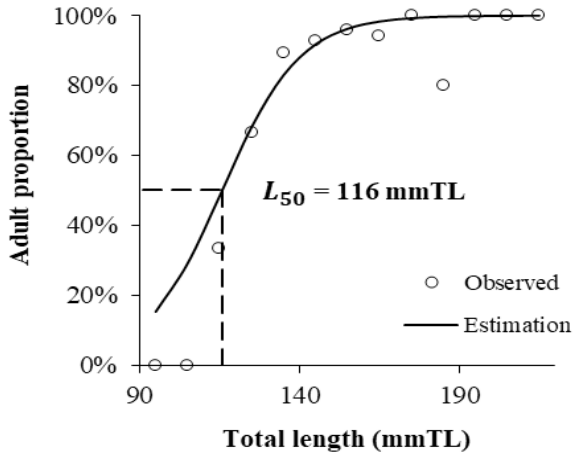

Figure 4. Size at 50% maturity of bonylip barb in Tamblingan Lake during January-December 2019

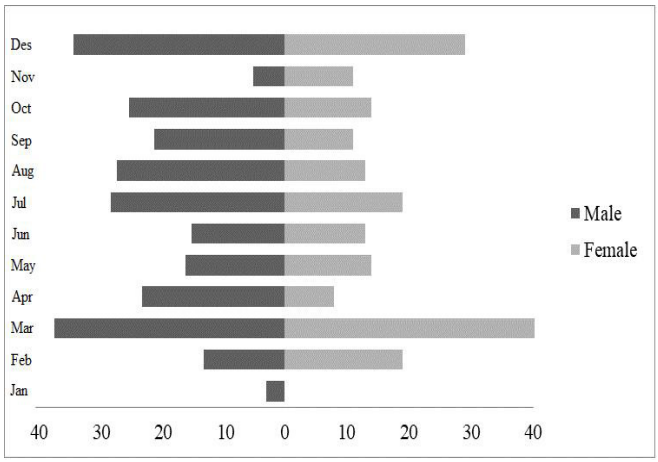

Figure 5. Sex ratio of bonylip barb in Tamblingan Lake during January-December 2019

The gonadosomatic index (GSI) of male fish was smaller than female fish. The range of GSI for male fish was between 0.16-15.50 and female fish 0.48 - 32.73 (Table 2). The highest GSI of male and female was found in March, while the lowest was found in July. GSI average of bonylip barb in Tamblingan Lake always increase along with the increase of GMS, except for the GMS V which is the fish have spawned (Table 3).

The fecundity was counted from 192 mature female fish (GMS III and IV). The number of eggs increased with the increase of the maturity stage. The fecundity of bonylip barb in Tamblingan Lake ranged from 2,792-279,326 eggs (Table 4). The highest number of eggs was found in March (279,326 eggs) and the lowest was in June (2,792 eggs).

The mature bonylip barbs were always found at each sampling time (Table 5). The mature fish were also found at each observation station during sampling. Most of the mature fish were found in March. The fish in mature condition (male and female) were mostly found at station 1 and 5.

3.2 Discussion

The length-length relationship of bonylip barb has a strong correlation to the bodyweight. Fork length was the most accurate parameter to estimate the bodyweight than the other length parameter. The growth pattern of bonylip barb in Tamblingan Lake was isometric which indicates the rate of increase in the length of the fish is simultaneous with the increase in weight. This species has different growth pattern in other aquatic ecosystems (Table 6). The differences in growth patterns were influenced by habitat conditions (Jusmaldi and Hariani, 2018), sex (Jusmaldi *et al*., 2020a), season (Djumanto *et al*., 2020), sampling time (Famoofo and Abdul, 2020), and several other factors.

The length at first maturity of bonylip barb in Tamblingan Lake was 116 mm TL. That length was longer than bonylip barb in Rawa Pening Lake (Rochmatin *et al*., 2014), but shorter than bonylip barb in Singkarak Lake (Uslichah and Syandri, 2003) and Telaga Lake (Putri *et al*., 2015). The factors that determine the length at first maturity is the environmental condition (Pérez-Palafox *et al*., 2022), food availability (Karna and Panda, 2011), and the growth somatic factor (Kılıç and Becer, 2016). Information of the length at first maturity is an important key parameter to manage the fish stock population, so that the caught fish have spawned at least once.

The sex ratio can be used to predict the success of spawning, recruitment, and management of fish resources. The results of the sex ratio using chi-square analysis showed that the proportion of male and female fish was unbalanced ($p<0.05$) with more male fish than

female fish. The sex ratio of bonylip barb in Tamblingan Lake was influenced by spawning time. The male fish of family Cyprinidae tend to aggregate on spawning time, including the immature fish (Sousa-Santos *et al*., 2014). Omar (2010) and Jusmaldi *et al.* (2020b) found more female fish than male fish in Sidenreng Lake (South Sulawesi) and in Benanga Reservoir (East Kalimantan). A similar condition was also reported by Maulidyasari and Djumanto (2020) at Rawa Pening Lake, Semarang. Meanwhile, Dewantoro *et al.* (2019) reported that the sex ratio of *Osteochilus schlegelii* was balanced in the Kapuas River and Sekayam River (West Kalimantan). The sex proportion of male *Osteochilus waandersii* fish in the Landak River is more dominant than female fish (Soetignya *et al*., 2020).

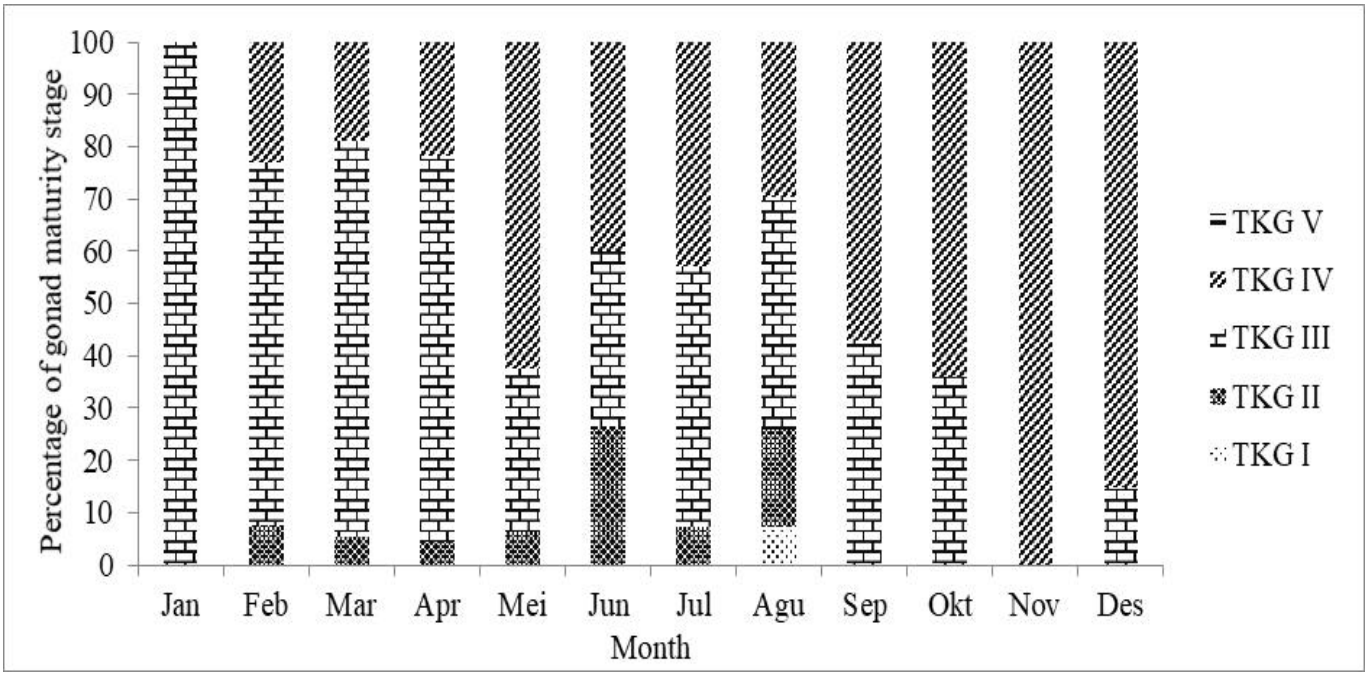

Figure 6. Gonad maturity stage proportion of male bonylip barb in Tamblingan Lake during January-December 2019

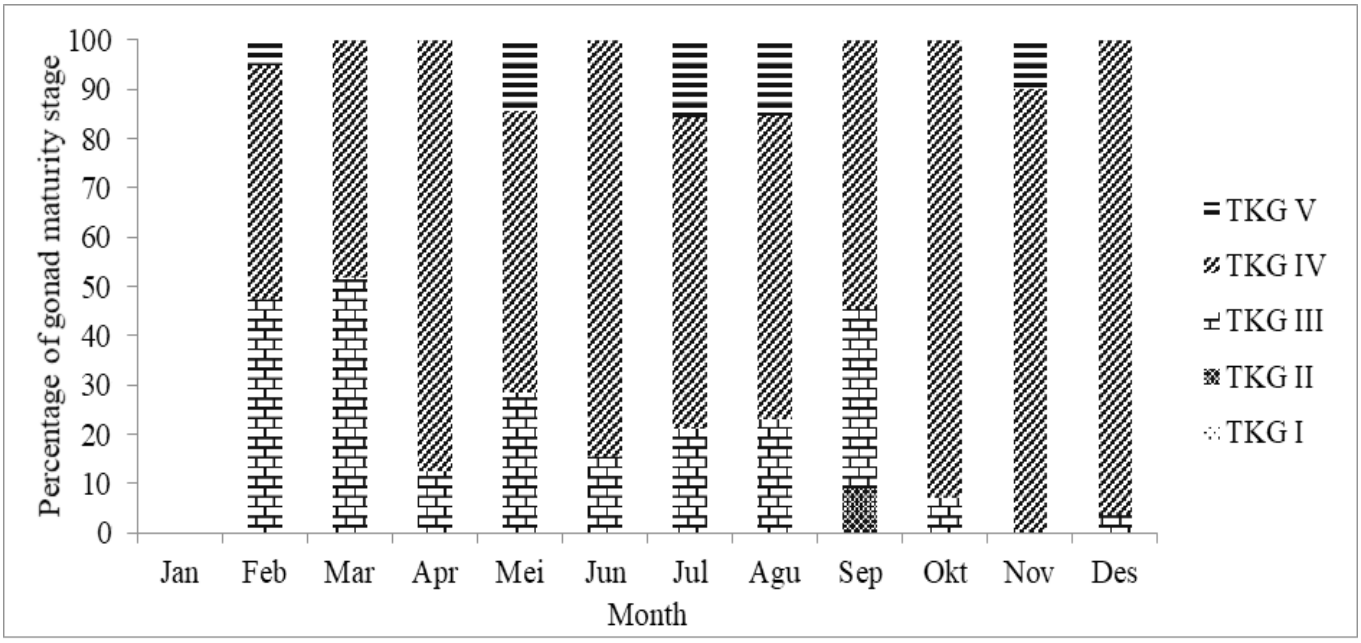

Figure 7. Gonad maturity stage proportion of female bonylip barb in Tamblingan Lake during January-December 2019

Table 2. Gonadosomatic index value of bonylip barb in Tamblingan Lake during Januray-December 2019

Month	Male		Average (Sd±)	Female		Average (Sd±)
	Min	Max		Min	Max	
January	5.09	11.33	9.13 (± 3.01)	0	0	0
February	2.14	12.71	8.53 (± 8.03)	2.59	29.27	21.79 (± 9.02)
March	3.85	15.5	9.22 (± 8.01)	7.45	32.73	21.17 (± 8.19)
April	3.03	15.35	6.83 (± 6.10)	5.63	25.27	15.46 (± 6.22)
May	1.05	9.42	3.82 (± 4.00)	0.89	17.42	9.28 (± 5.06)
June	1.19	5.75	3.32 (± 3.13)	3.69	13.39	7.58 (± 3.32)
July	0.16	5.59	2.95 (± 4.06)	0.48	17.97	9.24 (± 4.10)
August	0.96	7.23	3.35 (± 3.17)	2.87	19.85	8.94 (± 3.41)
September	3.35	10.04	5.49 (± 4.32)	6.6	19.92	14.31 (± 5.62)
October	5.28	12.93	8.67 (± 3.21)	4.92	17.84	12.79 (± 3.02)
November	4.54	8.97	7.08 (± 6.05)	4.44	27.4	17.46 (± 8.13)
December	0.91	12.65	8.99 (± 5.38)	10.69	24.14	17.38 (± 5.24)
Total	0.16	15.5	6.47 (± 7.04)	0.48	32.73	15.71 (± 7.42)

Table 3. Gonadosomatic index (GSI) value in every stage of gonad maturity stage of bonylip barb in Tamblingan Lake during January-December 2019

Gonad maturity stage	n	Male		Average (Sd±)	n	Female		Average (Sd±)
		Min	Max			Min	Max	
Gonad maturity stage I	2	0.96	1.41	1.18 (± 1.08)	0	0	0	0
Gonad maturity stage II	16	0.16	7.16	2.41 (± 6.08)	1	6.6		6.6
Gonad maturity stage III	116	0.41	15.5	6.19 (± 7.22)	56	3.69	30.41	15.28 (± 7.81)
Gonad maturity stage IV	113	0.17	15.35	7.43 (± 7.48)	136	4.27	32.82	16.83 (± 7.10)
Gonad maturity stage V	0	0	0	0	9	0.43	4.79	2.44 (± 2.07)

The differences in sex ratios of bonylip barb in different aquatic habitats can be caused by the behavior of these fish species in groups (Omar, 2010), so sex mixing will occur at the time of sampling. Several factors that influence the sex ratio of fish are genetics (Wedekind, 2017), differences in habitat conditions (Geffroy and Douhard, 2019), spawning time (Haryono *et al*., 2014), and temperature (Geffroy and Wedekind, 2020). A large number of female fish is one indicator of the availability of an abundant amount of food (Famoofo and Abdul, 2020), whereas when the male fish population is greater, it indicates a limited amount of food (Rostika *et al*., 2017).

Table 4. Fecundity of bonylip barb in every gonad maturity stage in Tamblingan Lake during January-December 2019

Month	Gonad maturity stage III				Gonad maturity stage IV			
	n	Min	Max	Average (Sd±)	n	Min	Max	Average (Sd±)
Jan	0	0	0	0	0	0	0	0
Feb	9	9,719	62,761	40,787(± 19,193.28)	9	44,766	79,200	64,824 (± 19,665.71)
Mar	27	7,842	173,482	50,785(± 61,739.16)	25	22,985	279,326	83,216 (± 61,007.89)
Apr	1	8,708		8,708	7	21,132	95,444	40,282 (± 20,039.36)
May	4	4,046	14,761	9,901(± 4,638.06)	8	15,441	50,331	30,183 (± 14,155.62)
Jun	2	2,792	13,754	8,273(± 4,653.02)	11	6,637	18,162	11,780 (± 4,699.25)
Jul	4	3,617	14,077	8,518(± 4,701.42)	12	5,942	20,203	11,683 (± 4,616.11)
Aug	3	7,483	10,779	8,766(± 10,335.95)	8	8,224	39,571	17,883(± 10,014.68)
Sep	4	11,593	15,876	14,053(± 2,797.23)	6	13,630	20,025	16,349 (± 2,833.94)
Oct	1	11,796		11,796	13	8,873	23,690	15,152 (± 4,588.29)
Nov	0	0	0	0	9	21,477	54,881	41,119(± 11,768.67)
Des	1	9,769		9,769	28	10,961	56,259	22,072(± 11,020.00)
Total	56	2,792	173,482	34,666(± 20,251.01)	136	5,942	279,326	35,906(± 39,586.54)

Table 5. Number of bonylip barb in mature condition based on month and sampling station in Tamblingan Lake during January-December 2019

Month	Male					Female				
	St. 1	St. 2	St. 3	St. 4	St. 5	St. 1	St. 2	St. 3	St. 4	St. 5
Jan	0	0	0	3	0	0	0	0	0	0
Feb	3	2	5	2	0	6	3	5	2	2
Mar	0	8	0	13	14	0	7	0	22	23
Apr	6	3	11	1	1	1	3	2	0	2
May	3	2	2	4	4	6	2	0	2	2
Jun	0	0	1	2	8	0	0	1	1	11
Jul	5	3	9	2	7	6	2	2	4	2
Aug	8	1	3	2	6	3	3	0	3	2
Sep	12	0	9	0	0	2	0	8	0	0
Oct	14	5	4	1	1	6	4	2	0	2
Nov	0	4	0	1	0	0	5	0	4	0
Des	27	2	3	0	2	14	4	9	0	2
Total	78	30	47	31	43	44	33	29	38	48

Table 6. Growth pattern of bonylip barb (*Osteochillus vittatus*) in the other aquatic ecosystem

No.	Location	Sex	b	Growth pattern	Reference
1	Tamblingan Lake (Bali)	Pooled	3.12	Isometric	This research
2	Rawa Pening Lake (Semarang)	Pooled	2.83	Negative allometric	Rochmatin *et al.* (2014)
3	Telaga Lake (Sulawesi Tengah)	Pooled	2.83	Negative allometric	Putri *et al.* (2015)
4	Buyan Lake (Bali)	Pooled	2.1	Negative allometric	Sravishta *et al.* (2018)
5	Rawa Pening Lake (Semarang)	Female Male	2.9 2.96	Negative allometric Negative allometric	Maulidyasari and Djumanto (2020)
6	Benanga Reservoir (Kalimantan Timur)	Female Male	3.19 2.97	Positive allometric Isometric	Jusmaldi *et al.* (2020a)
7	Temengor Reservoir (Malaysia)	Pooled	3.03	Isometric	Hamid *et al.* (2015)
8	Pahang River (Malaysia)	Pooled	3.12	Positive allometric	Zulkafli *et al.* (2015)
9	Tembeling River (Malaysia)	Pooled	2.85	Negative allometric	Zulkafli *et al.* (2016)
10	Raban Lake (Malaysia)	Pooled	2.71	Negative allometric	Piah *et al.* (2021)

The gonad maturity stage indicates when the fish will spawn, have just spawned, or have spawned. Mature fish were found every month of observation and with a total of 229 male fish and 192 female fish. The highest number of gonad mature fish was found in March, 35 male fish and 52 female fish. The highest gonadosomatic index value was found also in March for male and female fish. Hedianto and Purnamaningtyas (2013) stated that the spawning time of fish can be estimated by looking at the proportion of gonad mature fish and the highest of gonadosomatic index value. Based on the results, it can be assumed that the peak of the spawning of bonylip barb fish in Tamblingan Lake occurred in March or during the rainy season. Muchlisin *et al.* (2010) stated that the rainy season has a strong correlation with the spawning of fish that live in the tropics due to an increase in water mass in rivers and lakes. The value of the gonadosomatic index of female fish is always greater than the value of the gonadosomatic index of male fish. Similar conditions were also found by Uslichah and Syandri (2003) and Jusmaldi *et al.* (2020b). This is because the size and weight of the female fish gonads are larger than the male fish gonads.

The reproductive ability of fish has a very close relationship with the number of eggs that can be produced (fecundity). Fecundity is very important to determine the continuity of recruitment in the study of population dynamics and fish life history (Muchlisin, 2014). The fecundity of bonylip barb in Tamblingan Lake ranged from 2,792-279,326 eggs. Based on the reproductive

strategy, the bonylip barb fish in Tamblingan Lake is developed with the R Strategy (Reznick *et al*., 2002). The fecundity of bonylip barb in Tamblingan Lake is greater than of bonylip barb in Telaga Lake (Putri *et al*., 2015), Rawa Pening (Rochmatin *et al*., 2014), Singkarak Lake (Syandri *et al*., 2015) and in Sidenreng Lake (Omar, 2010). The fecundity of bonylip barb in Tamblinan Lake is greater because the length and weight is bigger than the previous research. Several factors that influence fish fecundity are the fish length and weight (Syandri *et al*., 2013; Rostika *et al*., 2017), food availability and nutritional content (Muchlisin, 2014; Tarigan *et al*., 2020), and differences in habitat (Syandri *et al*., 2015). Bonylip barb in Tamblingan Lake spawned throughout the year; this was evidenced by the constant finding of male and female on gonad maturing every month of observation. Similar conditions were also found in Telaga Lake (Putri *et al*., 2015). The mature fish were also found in all sampling stations. The mature fish were more commonly found in stations with environmental characteristics with aquatic plants such as at station 1 and 5. This was presumably because the female fish would attach its eggs to a substrate such as aquatic plants.

4. Conclusion

Length-length relationship of bonylip barb has a strong correlation to the bodyweight. All type of measurements were related strongly to the weight. The growth pattern of bonylip barb in Tamblingan Lake was isometric. The length at first maturity of bonylip barb in Tamblingan Lake was 116 mmTL. The sex ratio was imbalanced. The value of gonadosomatic index was between 0.002-0.327, the highest gonadosomatic index found in March. Fecundity of female fish ranged amongst 2,792-279,326 grain eggs. Mature fish was found in all stations during the sampling period and found on every month observation. The study will be helpful for future morphoregression and reproductive biology of bonylip barb (*O. vitattus*) in the Tamblingan Lake, Bali Island.

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Authors Contributions

All authors have contributed very well from devise research idea to the final manuscript before sent to JIPK managers. The contribution of each author as follow, I Nyoman Y. Parawangsa; collected the fish sample, analyzed data and wrote the scripts. Gede Arya Kusuma Artha; contributed to analyze the fish sample in laboratory and wrote the scripts. Prawira A. R. P. Tampubolon; contributed to collect the fish sample, analyzed data, and critical revision of the article.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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