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The Reproduction of Endemic Fish Opudi (*Telmatherina prognatha* Kottelat, 1991) in Lake Matano, South Sulawesi, Indonesia

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***Abstract*—*Telmatherina prognatha* is an endemic fish of the Matano Lake, in Indonesia, which demands a very crucial reproductive study, especially based on habitat conservation. This research, therefore, aims at analyzing its reproduction function as basic information for resource management in Matano Lake. Furthermore, the investigation was conducted from March 2018 to February 2019 in six sampling spots, where the habitat conditions, including the physicochemical characteristics of the water, were observed monthly. Also, the fish were sampled using a multifilament net that was 0.5 inches in mesh size and subsequently measured for total length, body weight, and gonad maturity. Moreover, the total number of specimens were approximately 1809 individuals (n), encompassing both sexes of male (1059) and female (750), which possessed a total length in the ranges of 36.46 – 72.00 mm and 32.93 – 66.20 mm, respectively. However, the sex ratio obtained was 1.4: 1, and those with matured and maturing gonads were found in each sampling's month, and most of all, including those with spent gonads, are commonly discovered in February, March, and April. Also, the 50% probability of maturity was estimated as 57.31 mm for males and 45.16 mm for females, while the mean gonadal somatic indices (GSI) were 1.72±1.39 and 4.12±1.74, respectively. Therefore, the fecundity of this species was estimated to be in a range of 77-299 eggs, and the oocyte diameter was between 0.11 mm and 1.37 mm.**

***Keywords*—Endemic fish; reproductive; *Telmatehrina prognatha;* Lake Matano.**

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I. INTRODUCTION

There is a high variation of endemic fish species in the ancient Matano Lake, situated around the complex of Malili Lake, and one of which is the *Telmatherinidae* family [1]. These water bodies possess a different height, which serves as a barrier for migrating organisms, especially from downstream to upstream. This brings about a unique organism distributing pattern with personalized endemic fish species, although the locations are close to one another [2].

The *Telmatherina prognatha* fish is classified in the family of *Telmatherimidae*, an ornamental species possessing beautiful colors. Also, it has secondary sexual characters, including different colors, shapes, or sizes, indicating dimorphism and dichromatism. This family, in general, shows mating behaviors, including (1) non-parental care, (2) spawning on substrates, (3) not exhibiting territoriality, and (4) often changing reproduction partners [3], and each species acquires different behaviors during spawning sessions. Furthermore, some behaviors in pairs are always shown by males and females include swimming near the bottom of the water column. However, some were occasionally seen in the middle of the water column. This is a tactic of avoiding interference from other males and practiced in seeking a proper spawning ground [3]. A research conducted by Nilawati [4] reported that the specie of *Telmatherina sarasinorum* prefers places shaded by trees within the surrounding of the lake. Moreover, they also spread across the littoral areas, either rocky or dense riparian habitat at the edge of the water body [5].

T. prognatha is included as an extinct fish according to IUCN [6]. Therefore, investigation about its reproduction is essential, enabling its use as baseline information, concerning habitat conservation. The related studies are highly limited to some species, including *T. celebensis* [7]-[9], *T. antoniae* [10] and *T. sarasinorum* [4], [11]. This research aims to analyze the reproduction of *T. prognatha,* later to serve as a fundamental source of information on fish resource management in the Matano Lake.

II. Materials and Method

A. Material

This study was conducted in the Matano Lake, Southeast Sulawesi, for 12 months, i.e., from March 2018 to February 2019, and the sampling locations composed of six stations, which include Lawa River, Wotu Pali, Salonsa Beach, Utuno, Petea River, and Tanah Merah (Figure 1).

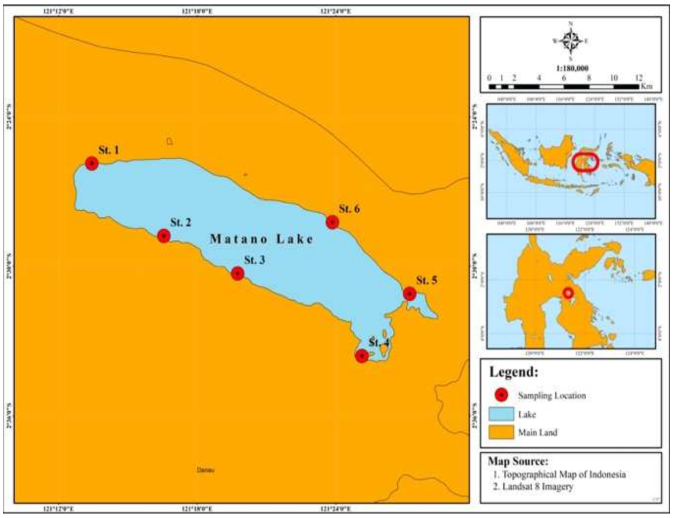

Fig. 1 Research location in the Matano Lake

B. Methods

Sampling fish was carried out once every month directly using a multifilament net in size of 30 m length, 2 m width, and 0.5-inch mesh size. The net was stretched on the upper column near-surface water shaping an angle range of 45^0-90^0 perpendicularly on the coastline in each station. The sampled fish were measured and weighted using calipers and an analytical scale with an accuracy of 0.01 mm and 0.001 g, respectively. These fish were then dissected, and their sexes were defined. Their gonads maturity development was divided into some levels [4], [12].

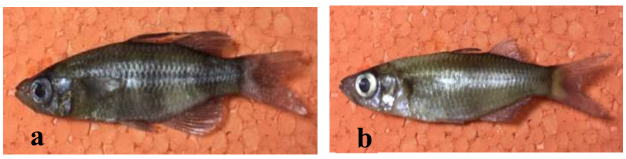

Fig. 2 Sampled fish of *Telmatherina prognatha* male (a) and female (b) Kottelat 1991

The determination of gonad maturity was assessed by morphologically observing shape, size, color, and gonads' content development. Hence they were subsequently classified into some stages of maturation [4], [12].

C. Data Analysis

1) Sex Ratio: This sex ratio analysis used the following formula.

$$X = \frac{M}{F} \quad (1)$$

Where:
X = Sex ratio
M = Number of male fish (individuals)
F = number of female fish (individuals)

Furthermore, a chi-square test was taken, using the formula [13] as follows.

$$X^2 = \frac{(Oij-Eij)^2}{Eij} \quad (2)$$

Where:
X^2= value of *chi-square*
Oij= frequency number of catches
Eij= expected frequency of occurrence

2) Fish Sizes of First Gonad Maturity: Supposing the first gonad maturity (Lm50) fish sizes was based on the total length of sampled fish applying the following formula [14].

$$P = \frac{1}{[1+e^{-r(L-Lm)}]} \quad (3)$$

Where:
P = probability of fish with gonad maturity (%)
e = exponential of natural number
L = average length (mm)
Lm = size of first gonad maturity (mm)

3) Gonadal Somatic Index: The Gonadosomatic Index (GSI) refers to the following formula [15].

$$GSI = \frac{GW}{BW} x100 \quad (4)$$

Where:
GMI= gonado somantic index.
GW= gonad weight (g)
BW= body weight (g)

4) Fecundity: Fecundity was calculated by applying a direct count method on fish eggs, one after the other. Therefore, its relationship with fish body length is involved using the formula [16] as follows.

$$F = aLb \quad (5)$$

Where:
F= number of eggs (item)
L= Total length (mm)
a and b= constants

III. Results and Discussion

A. Sex Ratio

During a sampling period, the total number of captured *T. Prognatha*, starting from March 2018 to February 2019, was about 1,809 individuals, consisting of 58.54% male and 41.46% female. Furthermore, the sex ratio utilizing the Chi-Square test with a significant level of 0.05 indicates an imbalance between both, at 1.41: 1, in which the $X^2_{table} > X^2_{count}$.

TABLE I
THE SEX RATIO OF FISH *T. PROGNATHA* SPATIALLY

Station	Male		Female		Sex Ratio	X^2 count
	Individual	(%)	Individual	(%)		
S. Lawa	175	16.53	102	13.60	1.72:1	19.24*
Wotu pali	100	9.44	63	8.40	1.59:1	8.40*

P. Salonsa	241	22.76	157	20.93	1.54:1	17.73*
Utuno	214	20.21	180	24.00	1.19:1	2.93
S. Petea	109	10.29	108	14.40	1.01:1	0.005
Tanah Merah	220	20.77	140	18.67	1.57:1	17.78*

Where: χ^2 table (0.05, 1) = 3.84; χ^2 table$\geq$ χ^2 count. A comparison of male and female = 1 : 1; (*) the comparison of male and female ≠ 1:1

Spatially, the ratio in each location possessed different values, and the females were always lesser, comparatively. However, the sampling point with the highest male was Lawa River (1.72:1), and two others recorded 1:1, including Utuno and Petea River (Table 1).

TABLE II
THE SEX RATIO OF FISH *T. PROGNATHA* TEMPORALLY

Month	Male		Female		Sex	X^2
	Individual	(%)	Individual	(%)	Ratio	count
March'18	88	8.31	75	10.00	1.17:1	1.04
April'18	95	8.97	63	8.40	1.15:1	6.48*
May'18	58	5.48	51	6.80	1.14:1	0.45
Jun'18	59	5.57	41	5.47	1.44:1	3.24
Jul'18	57	5.38	43	5.73	1.33:1	1.96
Aug'18	126	11.90	97	12.93	1.30:1	3.77
Sept'18	195	18.41	94	12.53	2.07:1	35.30*
Oct'18	89	8.40	88	11.73	1.01:1	0.01
Nov'18	151	14.26	89	11.87	1.70:1	16.02*
Dec'18	52	4.91	36	4.80	1.44:1	2.91
Jan'19	50	4.72	43	5.73	1.16:1	0.53
Feb'19	39	3.68	30	4.00	1.30:1	1.17

Where: χ^2 table (0.05, 1) = 3.84; χ^2 table$\geq$ χ^2 count. A camparison of male and female = 1 : 1; (*) the comparison of male and female ≠ 1:1

Temporally, the ratio during sampling periods was balanced, and the conditions where the ratio was ≠ 1: 1 were only detected in three months, encompassing April, September, and November. However, the highest and the lowest occurred in September (2.07:1) and October (1.01:1), respectively. Even though the sampling period, the male was dominantly caught than the females, although the Chi-Square test towards the species monthly resulted in a balanced proportion (Table 2).

Commonly, the sex ratio of *T. prognatha* was 1:1, except those found in the Lawa River station, which was ≠ 1: 1. This ratio was probably affected by several natural and environmental factors [17]. Also, some rainbow fish that also possessed this 1:1 ratio to include *T. celebensis* from Towuti Lake [7], and *T. antoniae* [18], while *T. sarasiunorum* [4] varied with sampling location and period, although the highest was recorded as 3.05:1. This imbalanced proportion was confirmed from observation during the spawning behavior as males fought over some females [4]. According to research conducted by Jayadi *et al.* [20], the small cyprinids fish (*Mystacoleucus padangensis*) occurs at a sex ratio of 1:1.99. The opposite occurs in Celebes rainbowfish (*Marostherina ledigesi*), where the male is smaller than the female [20]. This finding was also reported for the marmorated ricefish (*Oryzias marmoratus*) [21]. Also, preserving the fish population requires that the comparison between both sexes is expected to be balanced (1:1), or having more females [22]. Sulistiono [23] also explained that some differences between both genders were due to their activity in waters, adaptable ability, and genetic factors. Also, the movement can be influenced by the number of catch that affects the ratio [24].

B. Gonad Maturity Stage (GMS)

According to sampling locations and time, the percentage of gonadal maturity stage of *T. prognatha* fluctuated between male and female. Spatially, the highest and the lowest for the males with the GMS I were abundantly found in Lawa and Patea River, respectively, and those with the GMS I, II, III, and IV were commonly identified in Salonsa Island and Wotu Pali, respectively. Furthermore, those with GMS V were discovered in Utuno and Petea River, respectively (Figure 3).

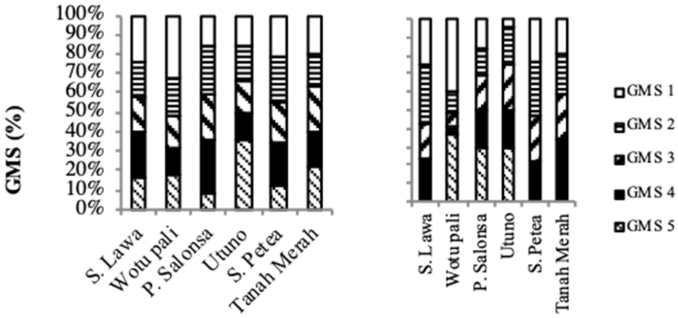

Fig. 3 The GMS percentage of male (left) and female (right) fish *Telmatherina prognatha* spatially

Conversely, the highest percentage of female fish were found in four locations, which include Wotu Pali (GMS 1), Utuno (GMS II and III), and Salonsa Island (GMS IV). Meanwhile, the lowest were discovered in two locations, encompassing Utuno (GMS II and III) and Wotu Pali (GMS IV). Also, the lowest with GMS V was only detected in three locations: Wotu Pali, Salonsa Island, and Utuno. Furthermore, a lower proportion of fish with matured gonads in Wotu Pali was presumed to be because the habitat is a nursery ground, indicating that it consists of rocky and rooty structures in the narrowly litoral area.

GMS I, III, and IV tend to dominate within each sampling period (Figure 4), with the highest male of GMS III and IV found in September and the lowest occurring in January and February. Meanwhile, the females were mostly noticed in August for GMS III, September, and December for GMS IV. However, those with spent gonad conditions (also with GMS III and IV), mainly females, were abundant in three consecutive months, including February, March, and April, implying that these were the peak season for spawning. Nevertheless, August to December also showed a high percentage compared to the remaining months of the year.

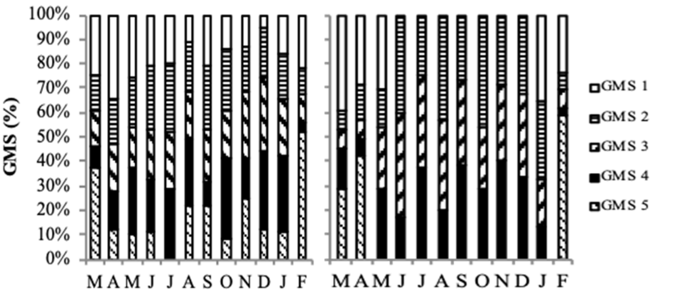

Fig. 4 The GMS percentage of male (left) and female (right) fish *Telmatherina prognatha* temporally

The sampling location and periods were determinants of the different percentages of fish and its GMS, where the value was highest from February to April and from August to December. Also, a similar pattern was also demonstrated by the GMI evaluations that were frequently higher in those months. Furthermore, those with gradual spawning on gonad had acquired gonadal maturity, comprising various stages with different percentages [25]. According to Nilawati [4], the amount of *T. sarasinorum* (GMS IV) in the late dry and the early wet seasons were presumed since those periods were the peak season of spawning, followed by the rise in water surface of the lake. The report of Mamangkey and Nasution [26] express that the GMS numbers of a goby fish, endemic to Sulawesi (*Glossogobius matanensis*), with different gonad maturity, occurred abundantly in two different depths (75 m and 100 m), with a peak of spawning that took place from March to April and October to December [24].

C. Sizes of First Maturity Gonad

The size of *T. prognatha* on first gonad maturity (reaching GMS IV) was 43.43 mm long and 1.4 g in weight for male, while the female spanned 39.00 mm in length and 0.82 g in weight. Therefore, the total lengths (TL) for both, with 50% probability maturing gonads, were 57.31 mm and 45.16 mm, respectively (Figure 5). Hence, revealing that at the same size, the females were comparably quicker to obtain maturity. This size is further related to their growth, environmental effects, and reproductive strategy.

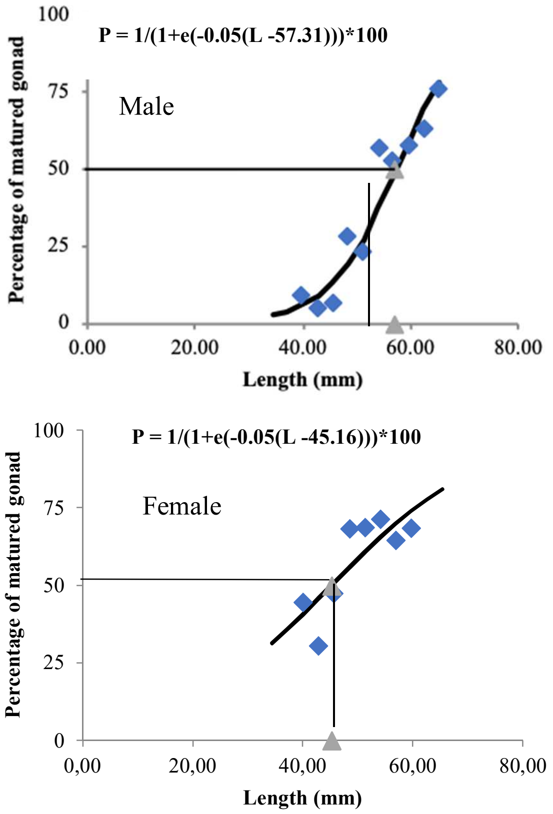

Fig. 5 The sizes of male and female fish *Telmatherina prognatha* with probability 50% maturing gonad

The first gonadal maturity (GMS IV) size for both male and female *T. prognatha* was 47.43 mm and 39.00 mm, respectively, and the highest number was obtained in September. Furthermore, an analysis of the results calculating 50% probability of gonadal maturity for both sexes recorded total lengths of 54.3 mm and 53.4 mm. Meanwhile, *T. celebensis* indicated a first gonadal development in the 37.3 mm long male and 36.4 mm for females [7], while the outcome of the current research demonstrates that more than 50% of the studied species were captured in the GMS III and IV. Also, a comparable result was obtained in the ricefish (*O. marmoratus*), where GMS I-V were noticed in every month [21].

D. Gonadosomatic Index (GSI)

The gonadal somatic index (GMI) was higher in line with the gonad maturity stage with a mean value of both sexes of fish in each location and period of sampling that signifies the male was smaller than the female at 1.72±1.39 and 4.12±1.74, respectively.

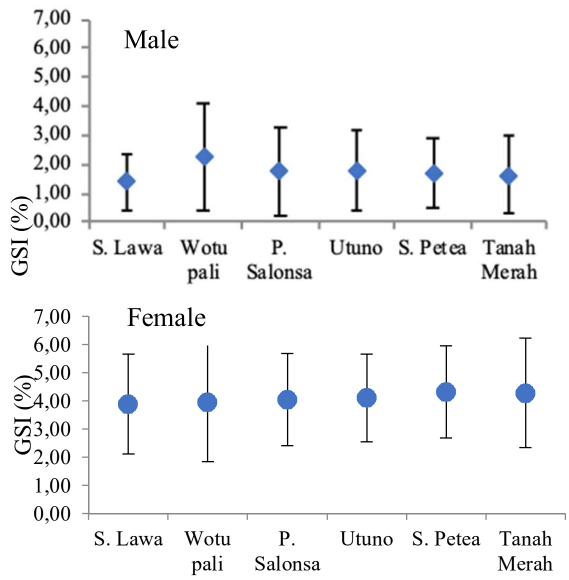

Fig. 6 The gonadosomantic index (GSI) of fish *Telmatherina prognatha* spatially

Spatially, the highest and the lowest mean of GSI for the male *T. prognatha* were located in Wotu Pali station (2.28±1.85) and Lawa River (1.39±0.9672), respectively. Furthermore, for the female were in Petea River (4.32±1.63) and Lawa River (3.88±1.77), respectively (Figure 6).

The highest and lowest mean of GSI for the male fish *T. prognatha* temporally occurred in March (4.39±1.96) and January (1.10±0.61), respectively, while that for females was in March (5.37±2.04) and February (3.06±1.28), respectively (Figure 7). Figure 7 infers that the most significant record ensued in five months, including March, May, September, November, and December, indicating that spawning is higher in these periods.

The GSI values of female *T. prognatha* were generally higher, which is similar to the report by Jayadi *et al.* [9], with outcomes for the female *T. celebensis* being more (1.58-2.64%) than the male (0.38-0.82%). These results enable the indication of reproductive activity peaks, as the highest and lowest for the male *T. prognatha* were recorded in March and July, respectively, while the least for females occurred in April. However, on four months (March, May, September, November, and December), the values were observed to commonly be higher than others, although the index fluctuates, which enables the indication that spawning occurs on time [22].

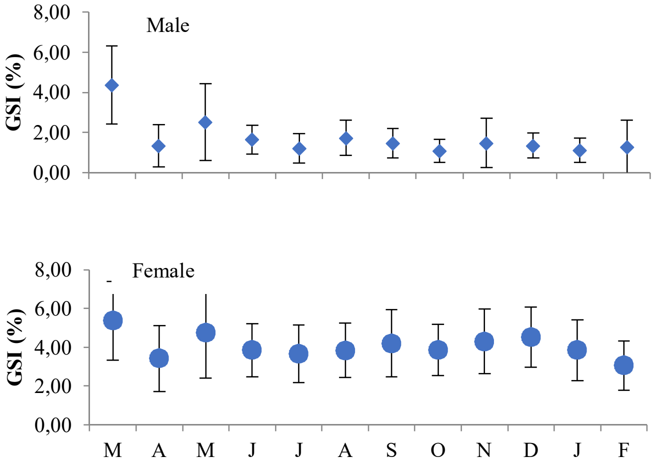

Fig. 7 The gonadosomantic index (GSI) of fish *Telmatherina prognatha* temporally

This finding was not similar with the study by [9], where the GSI peaks for *T. celebensis* in the Matano Lake happened in June and October while in Towuti Lake, it occurred in two months (November and February). Also, different spawning periods of Japenese whiting fish (*Sillago japonica*) appeared in two different locations of capture [27], where the highest value for both sexes was from April to August, and May, respectively [28]. This result indicates the variance of the period based on species and the ecological property of the habitats [29].

E. Fecundity

The fecundity of *T. prognatha* was at an average of 150 (GMS IV), with the lowest (77 eggs) occurring *int* fish that has a total length of 57.20 mm, and the highest (299 eggs) was from a 66.05 mm long type. Furthermore, the coefficient correlation of the regression equation test shows r = 0.16 (Figure 8), demonstrating a relationship between fecundity and the total length of *T. prognatha*. Also, it can also be inferred that the number of eggs in the ovaries were incapable of being surmised through the length data obtained.

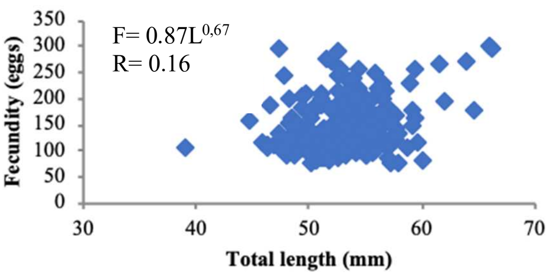

Fig. 8 The relationship between fecundity and the total length of fish *Telmatherina prognatha*

Fecundity is highly related to the environment, based on the existence of observed proportional changes [23], and the result obtained for *T. prognatha* was in a range of 77-299 eggs, with the average of 178 eggs. This result is well known to be affected by age, size, species, food abundance, season, and environmental conditions [29]. Furthermore, the data obtained signify that total lengths of *T. prognatha* possessing the lowest and highest values were 50.58 mm and 66.05 mm, respectively. Meanwhile, [9] expressed the fecundity of *T. celebensis* in Matano Lake to be within the range of 297-1,265 and that in Towuti Lake was 185-1448 eggs [7]. Nilawati [4] conveyed *T. sarasinorum* has a range of 64-488 eggs, while that of Celebes rainbowfish *Marosatherina ladigesi* defers, depending on the food type eaten, although when fed with *Daphnia* sp., 65-281 eggs were recorded [20]. These differences may be due to the larger age class used in the calculations [17], while Jayadi *et al.* [20] indicated that low fecundity was presumed to be related with small body shape, as seen in the Celebes rainbowfish (*M. ladigesi*).

In terms of the correlation with total length, the numbers of *T. prognatha* eggs were not predictable, which is in line with Karyanti [30], stating that fecundity had a weak association with length and weight. Furthermore, a low R^2 value demonstrates the absence of a relationship [22], [23]. However, research conducted by Suryanti [31] indicated a positive correlation in small cyprinids fish (*M. padangensis*) located in Naborsahaan, where an upsurge followed the increase in length and weight in the rate of fecundity.

IV. Conclusion

The sex ratio obtained was 1.4: 1. Size of maturity was estimated as 57.31 mm for male and 45.16 mm for female, the fecundity of this specie was estimated to be in a range of 77-299 eggs, and partial spawner. The peak of spawning occurs in February-April with spawning areas around the area of P. Salonsa and Utuno.

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