Population dynamics of Macrobrachium sintangense and M. lanchesteri in Lake Lido, West Java

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Abstract. Macrobrachium is a genus of freshwater prawn widely distributed in tropical and subtropical waters. Its two species found in Lake Lido, i.e Macrobrachium sintangense and M. lanchesteri. Macrobrachium sintangense is an indigenous prawn species from Indonesia while M. lanchesteri is an introduced species. The objective of this study is to identify the growth pattern, mortality rate, and recruitment pattern of both. The study was conducted from July to December 2015. The results show that the growth parameter carapace asymptotic length (CL∞) of M. sintangense and M. lanchesteri were 20.50 mm and 18.50 mm, respectively; and the growth coefficient (K) were 1.02/Year and 1.10/Year, respectively. The exploitation rate of M. sintangense were 0.68 and 0.81 thus both have exceeded the optimum exploitation rate. Therefore, these species can be considered as overexploited. The recruitment of the two species was performed twice per year. During the study, the population of M. sintangense happened to ceased in December 2015. An extra six-month study was conducted to see the recovery of this population, however M. sintangense had been extinct since then. It is suspected that there had been a natural competition between the native M. sintangense and the introduced M. lanchesteri.

Keywords: Population dynamic, macrobrachium, lake lido

1. Introduction
Freshwater prawn is an important resource in artisanal inland water fishery. The one, which is widely distributed in tropical and subtropical waters is that of the genus Macrobrachium [1]. In Africa, the freshwater prawn supports the inland water fishery and is an important source of animal protein and has a potency to be cultivated [2, 3].

Lido Lake is a semi-natural lake constructed in the 18th century by damming Ciletuh river and receiving seepage from surrounded Pondok Gede and Cigombong plantations [4]. This 21-hectare eutrophic lake is located at an altitude of 500 m above sea level [5]. The northern and eastern parts of Lido Lake are residential areas, while the western part is a tourism area and a rice field [6].
The presence of Sunda river prawn (*Macrobrachium sintangense*) in various places was reported by [7]. However, the current presence of this prawn is declining. This phenomenon can be found in Malahayu Reservoir, Central Java and Lake Cangkuang-Garut in West Java provinces. Two contributing factors are its habitat degradation and an existing pressure from aquatic invasive species that tend to be dominating the habitat, such as the glass prawn (*M. lanchesteri*). This glass prawn was accidentally brought together with an introduced fish such as tilapia fish [8]. A similar situation of such pressure in other part of the world can also be found in Mississippi River, where the *Macrobrachium ohione* population was declining due to habitat degradation, presence of predator, and high exploitation [9].

Research on the population dynamic of *M. sintangense*, a native prawn species of Indonesia, has been conducted by [10]. Her research was on the population structure and the reproduction period of *M. sintangense*. However, other research information related to the population dynamics of this species has not been available yet. Therefore, this research was to be carried out with the aims to identify the growth pattern, the mortality rate, and the recruitment pattern of the *M. sintangense*. The results of this study can serve as basic information for the management consideration, sustainable use and conservation of this native Indonesian prawn.

2. **Material and methods**

This research was conducted in Lake Lido (figure 1) that is geographically located between 106°48'26"–106°48'50"E and 6°44'30"–6°44'58"S in Cigombong District, Bogor Regency, West Java Province, Indonesia. The study was carried out in three steps, i.e. firstly, a preliminary survey in June 2015 to determine the specific sampling sites of *M. sintangense* and *M. lanchesteri* by a purposive method; secondly, a series of collection of the specimens of *M. sintangense* and *M. lanchesteri* every month on the 15 and the 19, respectively starting from July 2015 till December 2015 at the determined sampling sites; and lastly, additional samplings performed from January to May 2016 and in May 2017 to get more information about the population pattern of the two *Macrobrachium* species.

![Figure 1. Map of research location (●) in Lido Lake.](image)

2.1. **Sample Collection**

Prawn samples were collected by using a push-net for 120 minutes in 10 meters long. The primary data collected were: sex, and carapace length (mm). The specimens were directly identified based on Wowor *et al.* [10], their genders were determined according to Kayshap [11]. Carapace lengths were
measured by using digital calliper with an accuracy of 0.01 mm (figure 2). Carapace length is the distance between the middle edge of carapace and the back edge of the eye [12].

![Figure 2. Measurement the length of carapace (CL)](image)

All *M. sintangense* specimens were released back to their habitat due to its low number, while all specimens of *M. lanchesteri* were preserved in 96 % alcohol and they were measured and sexed in the Integrated Laboratory, Biology Department, School of Mathematics and Natural Sciences, Bogor Agricultural University.

2.2. Data analysis

The specimens of adults were separated from the young ones. The specimens with carapace length of more than 5 millimetres were grouped as adults. The adult females were further separated into two groups, i.e. female without egg and ovigerous female (carried eggs). The specimens with the carapace length of less than and equal to 5 millimetres were then grouped as young and their gender was not determined.

The recruitment pattern, growth pattern (K), mortality estimation (M) and exploitation rate were analysed by using FiSAT II [13]. Growth pattern (K) was estimated by using ELEFAN I tool, while mortality rate (M) were obtained through Pauly empirical equation [14]. The lifespan was estimated by using below equation:

\[ \text{lifespan} = t_0 + \left( \frac{2.996}{K} \right) \]

\[ t_0 = \text{theoretical Age}; K = \text{Growth Coefficient} \]

2.3. Water quality

Several physical and chemical parameters of surface water were measured. The physical parameters were temperature and pH, while the chemical parameters were DO (Dissolved Oxygen), COD (Chemical Oxygen Demand), ammonia (NH₃), and BOD (Biochemical Oxygen Demand). A thermometer and pH meter were used to measure the temperature and the pH respectively. DO and BOD were measured by performing Winkler-Alkali iodide azide method while COD, Pb, ammonia (NH₃) were measured by spectrophotometric method.

The data obtained are analysed and compared with the water quality standard based on the Indonesian Government Regulation No. 82/2001 on Water Quality Management and Water Pollution Control.

3. Results and discussion

3.1. Recruitment

The population size of a species in a water body is determined by various factors, such as recruitment through spawning aggregation and or restocking of the species, natural mortality and fishing [15]. The recruitment patterns of *M. sintangense* and *M. lanchesteri* consisted of two overlapping modes in one year. It means that these two species have partial spawner recruitment pattern. Figure 3 shows the different yearly peak recruitment of each. The peak recruitment of *M. sintangense* was in March to
April and August to September, while the peak recruitment of M. lanchesteri was in April to May and July to August.

The results of this study were in line with the research conducted by [10] in Lake Lido; M. sintangense spawned throughout the year and the maximum spawning activity occurred between March and June, which was starting at the end of rainy season and was ending at the early dry season. According to Said et al. [7] the peak spawning season for M. sintangense in Lake Sentarum, West Kalimantan Province, Indonesia was between March and April, i.e. at the end of rainy season.

In Myanmar, M. lanchesteri produced eggs throughout a year with the main reproductive period occurred during June to November and it was coinciding with rainy season [16]. Contrary with the M. lanchesteri in Lake Lido, West Java Province, Indonesia, the spawning season occurred two times per year, i.e. in the end of raining season and at the end of dry season. Macrobrachium vollenhoveni from Fahe Reservoir has also two recruitment peaks in a year, i.e. August and September to November [17], while the same species in Lagos-Lekki lagoon system in Nigeria has slightly different recruitment time, i.e. September to November and February [18]. High additional rate of new individuals in recruitment peak is caused by high food availability during those months [19]. According to Abohweyer and Falaye [18], two peak recruitment pattern in same year is a common recruitment pattern for short-lived tropical fish.

### 3.2. Growth Pattern

The growth coefficient (K), the asymptotic length (CL∞), the theoretical age at size 0 millimetre (t0) and the lifespan of M. sintangense and M. lanchesteri are presented in Table 1. The growth coefficient of M. sintangense was 1.02/year while for M. lanchesteri was 1.1/year. This data showed that M. lanchesteri grew faster than M. sintangense.

![Figure 3. Recruitment pattern of (a) M. sintangense and (b) M. lanchesteri.](image)

| Types of Prawn | K (year) | CL∞ (mm) | t0 (year) | Lifespan |
|----------------|---------|----------|-----------|----------|
| M. sintangense | 1,02    | 20,50    | -0,17     | 2,80     |
| M. lanchesteri | 1,1     | 18,50    | -0,16     | 2,60     |
The body size of *M. sintangense* is relatively larger with asymptotic length of 20.50 millimetres than that of *M. lanchesteri* with asymptotic length of 18.50 millimetres. According to Said *et al.* [7], a three-month old *M. sintangense* had approximately body size of 10-21 millimetres. Based on [20] *M. lanchesteri* can reach 55 millimetres body length. A further comparison with that of other species, *Macrobrachium vollenhoveni* in Lobe River had a bigger asymptotic length, i.e. 54 millimetres with growth coefficient (K) 3.19/year [21]. In Riberia River, growth coefficient of *M. acanthurus* 0.49/year for male and 0.42/year for female with asymptotic length is bigger, i.e 75.70 millimetres for male and 71.40 for female [22]. According to Bentes *et al.* [23], *M. amazonicum* in Amazon Estuary has asymptotic length of 36.50 to 46.90 millimetres and growth coefficient of 0.2 to 0.44/year. So, compared to other *Macrobrachium* genus, *M. sintangense* and *M. lanchesteri* have distinctly smaller body size. The differences in body length apparently are affected by heredity, sex, age, parasite, disease, environmental condition, and time difference in data sampling [15].

Based on the values of K and CL∞ which were applied to von Bertalanffy growth formula the estimated growth curves for *M. sintangense* and *M. lanchesteri* were then constructed (figure 4). The estimated growth curves indicates the expected lifespan of *M. sintangense* was 2.8 years and *M. lanchesteri* was 2.6 years. According to Dwiono [24] *M. lanchesteri* in Mekong river NongKhai has similar life span i.e 2.83 years. In Japan, the lifespan of female *M. nipponense* was estimated 2 years and 4 to 10 months, the male was 3 years and 4 to 9 months [25].

![Figure 4. Von Bertalanffy growth chart of *M. sintangense* (a) and *M. lanchesteri* (b)](image)

3.3. Mortality and Exploitation Rate (E)

Growth and mortality parameter estimations are the fundamental estimation in fisheries management, so they have become bases in determining fisheries management strategy [26]. The natural mortality (M) of *M. sintangense* was 1.94/year and the mortality caused by fishing (F) was 4.05/year (table 2). It
shows that the mortality of \(M.\ sintangense\) is more due to fishing. Therefore, the exploitation rate became high, i.e. 0.68/year. It was similar with \(M.\ lanchesteri\) which had a high mortality due to fishing (9.00/year) and a low natural mortality (2.08/year) which caused the exploitation rate of this species became high, i.e. 0.81/year. All these mean that both \(M.\ sintangense\) and \(M.\ lanchesteri\) have bigger fishing pressure.

### Table 2. Mortality and exploitation rate of \(M.\ sintangense\) and \(M.\ lanchesteri\)

| Prawn species              | \(Z\) (/year) | \(M\) (/year) | \(F\) (/year) | \(E\) (/year) |
|----------------------------|----------------|---------------|---------------|---------------|
| \(Macrobrachium\ sintangense\) | 5.99           | 1.94          | 4.05          | 0.68          |
| \(Macrobrachium\ lanchesteri\) | 11.08          | 2.08          | 9             | 0.81          |

\(Z\) = Total; \(M\) = Natural mortality; \(F\) = Fishing mortality; \(E\) = Exploitation rate

According to fishermen and local people around Lake Lido, \(M.\ sintangense\) had been the target of fishing since a long time ago. Consequently this activity increased the exploitation rate to 0.68 which exceeded its optimum limit. The exploitation rates of \(M.\ sintangense\) and \(M.\ lanchesteri\) have already reached its saturation condition. The same fishing pressure also happened with \(M.\ macrobrachion\) in Cross River which also had a bigger fishing mortality rate compared to its natural mortality. So, the declining of the population of \(M.\ macrobrachion\) was caused by the high pressure of fishing or exploitation [27]. According to Gulland in Pauly [14], the optimum exploitation rate of a resource is 0.5 or when its mortality rate due to fishing is equal to its natural mortality.

### 3.4. Population Composition of \(M.\ sintangense\) and \(M.\ lanchesteri\)

The total number of the freshwater prawn caught from Lake Lido during this six month study was 13,444 individuals which consisted of 306 \(M.\ sintangense\) and 13,138 \(M.\ lanchesteri\). The composition of \(M.\ sintangense\) comprising of 56 young, 103 adult females (including 16 ovigerous females) and 69 adult males. Quite the contrary, \(M.\ lanchesteri\) was more abundant with 3,691 young, 4,119 adult females (including 1,064 ovigerous females) and 2,681 adult males.

At the last month of the study, December 2015, not a single \(M.\ sintangense\) was encountered. Therefore, an additional seven month (January – May 2016 and May 2017) sampling activity was conducted to discover the return of \(M.\ sintangense\) population. However, the population of \(M.\ sintangense\) had never regained (figure 5) during the additional sampling time.

![Figure 5. Population composition of \(M.\ sintangense\) and \(M.\ lanchesteri\) in Lake Lido.](image)
The number of ovigerous female of *M. sintangense* was much smaller compared to that of *M. lanchesteri* (figure 6). The fecundity of *M. sintangense* was between 25 to 148 eggs [7]. As for the fecundity of *M. lanchesteri*, it was around 59-393 eggs (Suzuki and Ohtomi 2005). Therefore, the capacity of a female *M. sintangense* to produce offspring was lower than that of a female *M. lanchesteri*. Combined with the fact that only few number of the ovigerous female of *M. sintangense* was available, it caused a low number of young *M. sintangense* produced compared to that of young *M. lanchesteri* generated in a one spawning period (figure 7). During the study, the population of *M. sintangense* was decreasing and there was no single *M. sintangense* encountered since December 2015. In the long run not only *M. lanchesteri* will outnumber *M. sintangense*, but will also win the competition in getting food source. Such domination of *M. lanchesteri* in lakes was also reported through several studies such as in Lake Kerinci [23] and Lake Teluk [24] in Sumatra, and several small satellite lakes along Ciliwung and Cisadane Rivers in Java.

**Figure 6.** Quantity of *M. sintangense* and *M. lanchesteri* spawn female.

**Figure 7.** Quantity of young *M. sintangense* and *M. lanchesteri*.

Besides that, freshwater crayfish (*Cherax quadricarinatus*), which is also an introduced crustacean species, is obviously also present in Lake Lido. A good number of young *C. quadricarinatus* were obtained during all sampling time. It was a sign that *C. quadricarinatus* was already well established in the lake. The presence of these two introduced crustaceans are suspected to cause a very big
pressure to the existence of the native *M. sintangen* and to promote to the extinction of this species. A similar decline pattern of *M. sintangen* population was also present in Malahayu Reservoir, Central Java Province. The decreasing population size was allegedly caused by stocking of a predacious catfish, Pangasius sp [7].

### 3.5 Water Quality

The measured environmental parameters such as water temperature, acidity (pH), and environmental chemical parameters are presented in Table 3 below.

**Table 3.** The results of water physical and chemical measurement in Lake Lido

| Parameter       | Unit | M1  | M2  | M3  | M4  | M5  | M6  | Quality standard (*) |
|-----------------|------|-----|-----|-----|-----|-----|-----|----------------------|
| **Physical**    |      |     |     |     |     |     |     |                      |
| Temperature     | °C   | 26.5| 26  | 25  | 25  | 25.5| 25  | -                    |
| pH              |      | 6.5 | 7.67| 6.7 | 7.05| 6.95| 6.92| 9-Jun                |
| **Chemical**    |      |     |     |     |     |     |     |                      |
| DO              | mg/L | 6.1 | 3.7 | 4.5 | 7.1 | 6   | 6   | >3                   |
| COD             | mg/L | 38  | 35.6| 42  | 8   | 14  | 19  | <50                  |
| BOD             | mg/L | 15  | 15.1| 18.3| 2   | 4   | 1   | <6                   |
| Pb              | mg/L | <0.03| <0.03| <0.03| <0.03| <0.03| <0.03| <0.03                |
| Ammonia NH₃     | mg/L | -   | -   | 0.05| 0.01| 0.02| 0.05| -                    |
| Weather Condition |     | Bright | Bright | Bright | Rain | Rain | Flood/rain |                      |

*Quality standard No. 82 Year 2001 (Class III)*

The average temperature was 25.5°C. This was considered as low because the temperature was measured in the morning. However, this temperature is still tolerable by aquatic organisms in tropical area. According to [4], the optimum temperature of *M. sintangen* ranges between 24.8 and 32.3°C while the temperature of *M. lanchesteri* is between 25.5 and 33.5°C. It shows that the water temperature of Lake Lido is still within the optimum range for both species and *M. lanchesteri* can tolerate warmer water compared to *M. sintangen*. The pH water during the study was 6.9, which is a neutral acidity. According to New (2002), the optimum pH for freshwater prawn is 6.5 to 8.5. The DO values of all study periods were still in the range of quality standard at > 3 mg/L. This result was in line with the study conducted by New (2002) stating that the optimum DO that can support freshwater prawn is 3-7 mg/L. Chemical parameters such as COD, BOD, ammonia and Pb contents were still below the quality standard. It means that environmental parameters in Lake Lido were still appropriate for prawn organisms so that there must be other factors that caused the declining of *M. sintangen* population in Lake Lido.

Johnson [4] reported that *M. lanchesteri* could withstand extreme water condition such as tolerance to extreme temperature and low oxygen level. Furthermore, *M. lanchesteri* is also a species that can easily adapt to its surrounding habitat [16]. On the other hand, *M. sintangen* prefers to stay under shadow of big tree where the water temperature is usually lower than the water temperature of an open area. Nowadays, the big trees with good shadows become very rare around the lake as most of the trees and plants have been chopped leaving open areas around the lake. Therefore, that new environment condition becomes less suitable for *M. sintangen*.
4. Conclusion

Macrobrachium sintangense and M. lanchesteri have partial spawner recruitment which peak recruitment for M. sintangense was in March to April and August to September, while the peak recruitment of M. lanchesteri was in April to May and July to August. The asymptotic length of M. sintangense and M. lanchesteri were 20.50 mm and 18.50 mm, respectively, with growth coefficients of 1.02/year and 1.10/year, respectively. The exploitation rates of both M. sintangense and M. lanchesteri exceeded their optimum exploitation limit. The higher number of M. lanchesteri than M. sintangense indicates that M. lanchesteri dominates Lake Lido. Due to the dominancy, M. sintangense has lost since December 2015 and it has been considered nearly extinct from Lake Lido.

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