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Population Estimation of An Invasive Alien Species, Cherax quadricarinatus (von Martens, 1868) in Lido Lake, Indonesia

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ABSTRACT

Indonesia is a mega biodiversity country in the world, including native aquatic species. Some alien species could be a problem for aquatic biodiversity. The Redclaw crayfish or lobsters, Cherax quadricarinatus, is native in freshwater habitats of Australia. Unfortunately, C. quadricarinatus is also recognized as invasive, having already established wild populations in some lakes in Indonesia. The research was conducted to investigate the abundant of C. quadricarinatus as alien species in Lido lake, Indonesia. The research was conducted in October 2018 (transition) and February 2019 (wet season) at Lido lake, Bogor Resident, West Java, Indonesia. Around forty traps were installed along the lake line. Traps were set during the day and collected the next day. Caught lobsters were counted and marked on the carapace with nail polish and then the lobsters were returned to the lake. The Schnabel mark-recapture method is used in calculating abundance. The result showed that the abundant of C. quadricarinatus was high in October 2018 (N=2285) and February 2019 (N=2595) and the abundant of C. quadricarinatus was higher than native crustacean species, Macrobrachium sintangense, in Lido lake. There were slightly different ratio of C. quadricarinatus sex ratio between October 2018 and February 2019 but based on the chi-square test showed that in two periods data sampling were found not significantly different at the 95% level confidence. It was the first evidence that C. quadricarinatus could be an invasive alien species and it is well established in Lido Lake, Indonesia.

1. Introduction

Indonesia is one of the highest mega-biodiversity countries in the world, including the diversity of various aquatic species. Indonesia is also a hotspot of world biodiversity. The region of Indonesia has a complexity of biological unique, so it needs a variety of studies to determine its biodiversity (Sheldon et al., 2015). This region is globally threatened in diversity especially on biological components (Schipper et al., 2008). One of the causes and drivers of threats to biodiversity in Indonesia is invasive alien species (IAS) (Hughes, 2017; Sala et al., 2000). IAS is a plant, animal, fish, microorganism, and other organisms that are not part of an ecosystem that can negatively impact biodiversity, ecosystem disturbance, environment, economic losses, and human health (Fish Quarantine Center, 2017). IAS is considered the second largest threat to biodiversity, after habitat destruction (Austin et al., 2010). However, in the context of freshwaters (lakes, rivers, ponds, etc), IAS is considered a major agent of change in biodiversity, largely due to the intensive introduction of alien species (Sala et al., 2000).

One of the alien species that has spread in several countries is *Cherax quadricarinatus*. The *C. quadricarinatus* is crayfish species native to Australia and Papua New Guinea (Austin et al., 2010). This species has spread in several countries such as Malaysia (Awg Suhaili et al., 2016), Swaziland (Nunes et al., 2017), South Africa (Nunes et al., 2017; Petersen et al., 2017), Israel (Snovsky & Galil, 2011), USA (Snovsky & Galil, 2011), Zimbabwe (Marufu et al., 2014), Zambia and Mozambique (Nunes et al., 2016), Jamaica

(Pienkowski et al., 2015; Sacha-Renee Todd, 2005), Mexico (Bortolini et al., 2007; Torres-Montoya et al., 2016; Vega-Villasante et al., 2015), Puerto Rico (Pienkowski et al., 2015; Williams Ernest et al., 2001), Singapore (Belle & Yeo, 2010) and Slovenia (Jaklič & Vrezec, 2011). In Indonesian territory, this species has a native habitat in the Papua region (Adiansyah et al., 2016). However, *C. quadricarinatus* was found in Maninjau Lake (Dina, 2012), Lido Lake and Cilala Lake (Patoka et al., 2016).

Lido lake is one of the lakes where the water originating comes from the Cisadane River. Based on previous research conducted by Hadiaty (2017) states that in the Cisadane river flow including those whose flow of water originating from the Cisadane River has reduced the diversity of fish species from years 1910 to 2010, which is around 72.1%, from a total of 86 species to only 24 species of fish remain. According to Hestimaya (2010), there are 8 species of fish and 2 species of shrimp caught in Lido Lake, 5 species of fish are introduced species while 3 species are native. The results of Patoka *et al.*, (2016) showed that the species *C. quadricarinatus* has been able to breed well, as evidenced by the discovery of ovigerous females. It is feared that the presence of crayfish species in Lido Lake waters will threaten native species in those waters which can further threaten biodiversity in Lido Lake. This study aims to investigate the abundance of *C. quadricarinatus* as an alien invasive species in Lido Lake, West Java, Indonesia.

2. Material and Method

2.1 Description of the study sites

This study was carried out in Lido Lake, Bogor, West Java which is located at coordinates 106°48'26"-106°48'50" E and 6°44'30"-6°44'58" S. This study is to estimate an abundance of invasive species *C. quadricarinatus* in Lido Lake. The choice of location is based on previous studies conducted in Lido Lake. The choice of location is based on previous studies conducted in Lido Lake, Bogor Regency. Lido Lake waters have a variety of potential aquatic resources such as tourism, hospitality, and fisheries. Research locations are presented in Figure 1.

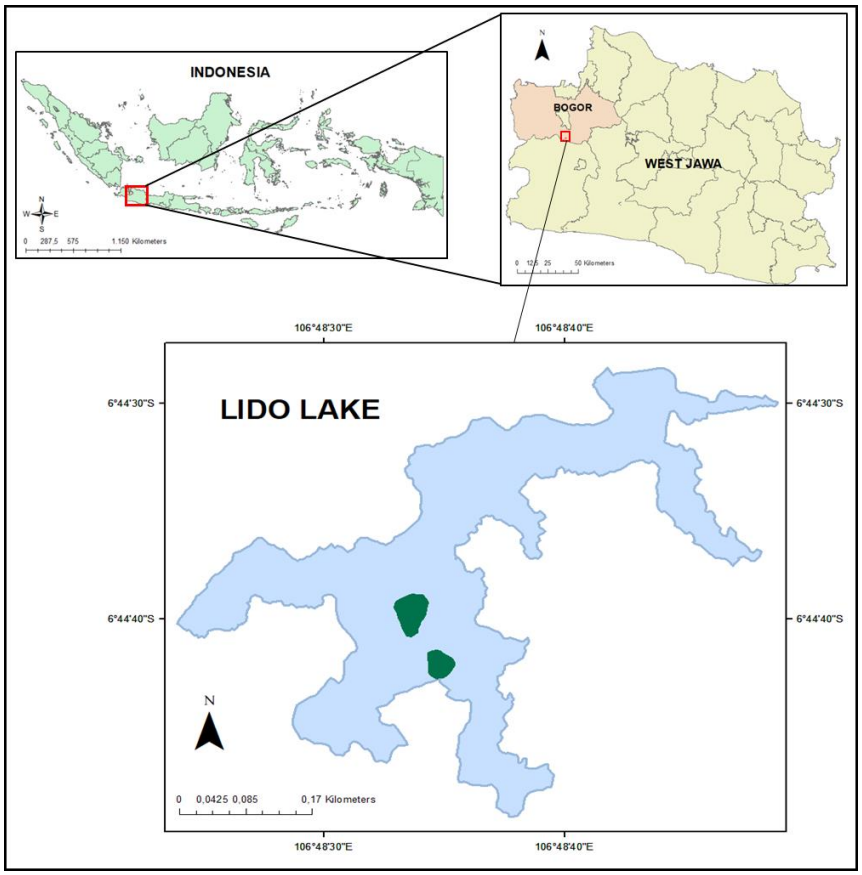


Figure 1. The location of Lido Lake, Bogor, West Java, Indonesia.

2.2 Data collection

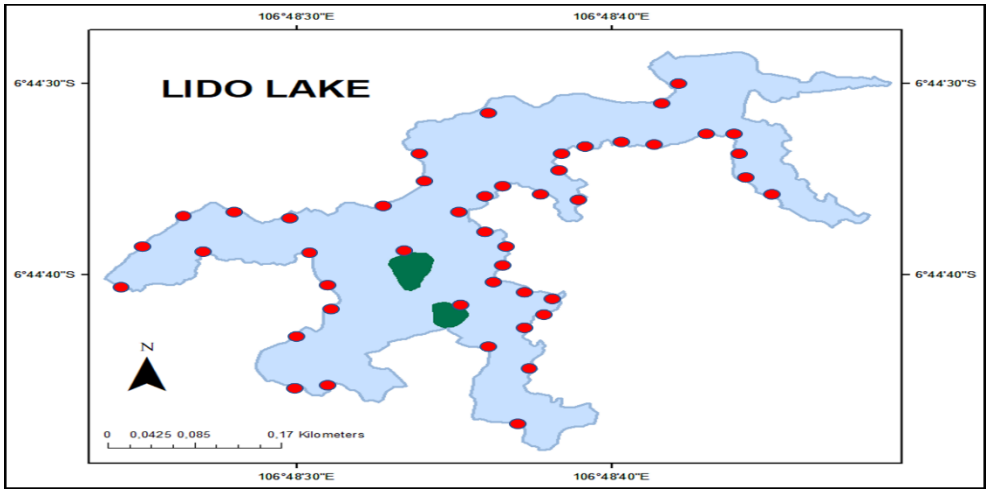
The field survey conducted in this study aims to retrieve data for the estimation of crayfish *C. quadricarinatus* population and water quality as a supported data. Data collection on crayfish abundance will be carried out in two different periods, which is in

October 2018 and February 2019. A sampling of water quality as a supported data was carried out after the second catch of data collection. Water quality sample analyzed by Proling Laboratory, Department of Aquatic Resources Management IPB University.

2.3 Mark-recapture data collection

Forty traps (Figure 2) were set along the lake line (Figure 3). Traps were set during the day and collected the next day. This based on *C. quadricarinatus* behavior as a nocturnal species. The bait used was a snail and fish chops and also freshwater algae as usually used by crayfish catcher. On the second day, the trap was lifted. Crayfish caught are counted and marked using nail polish on carapace then crayfish release to the lake and crayfish trap is set again for next capture. This step is repeated 10 times at intervals of 1 day. In general, data collection procedures using the Schnabel method to estimate the abundance of the population as follows (Savitri Dadan; Agustina, Fitriani, 2016):

Figure 2. Trap made of bamboo that used to catch crayfish.



● : sampling points

Figure 3. Observation points of population and water quality

1. The first step taken is to determine the place and what animals will be estimated in the abundance of population.
2. Capture; second step, what is done by capturing or taking samples from the population. This is a first step in estimating the abundance of the crayfish population. After the sample is obtained, the next step is counting the number of samples captured in the first sample.
3. Mark; third step, mark all the captured samples. Crayfish marking can be done in any way, the main requirement is that the marking is not easily disappearing. For the second sample, mark crayfish that have not been marked. Crayfish that have been previously captured or that have been marked didn't need to be marked.
4. Release; fourth step, release samples that have been marked into the lake.
5. Recapture; fifth step, re-capture samples and then return to the third step and so on, once again that for samples that have been marked, there is no need to be marked. Marking only for samples that have not been marked. Perform the procedure above until i-times.
6. Statistical calculations; the last step is to determine the estimated population of the animal using a Schnabel formulation and so the standard errors as follow:

$$\widehat{N} = \frac{\sum_{i=1}^{k} M_i n_i}{\sum_{i=1}^{k} m_i} \; ; SE = \frac{1}{\sqrt{\left(\frac{1}{N-\sum m_i} + \frac{k-1}{N}\right) - \sum\left(\frac{1}{N-n_i}\right)}}$$

2.4 Water quality observations

The water quality measured is temperature, pH, dissolved oxygen (DO), transparency, alkalinity and traps depth. The measurement of the water quality parameters was carried out after the second data collection crayfish catch. Analysis of the water quality environment requires water samples collected at each observation point. Water quality sampling points were around 37 sampling points. The number of water quality sampling points is not the same as the trap sampling point, this is because several trap sampling points that are close together are made into one water quality sampling point.

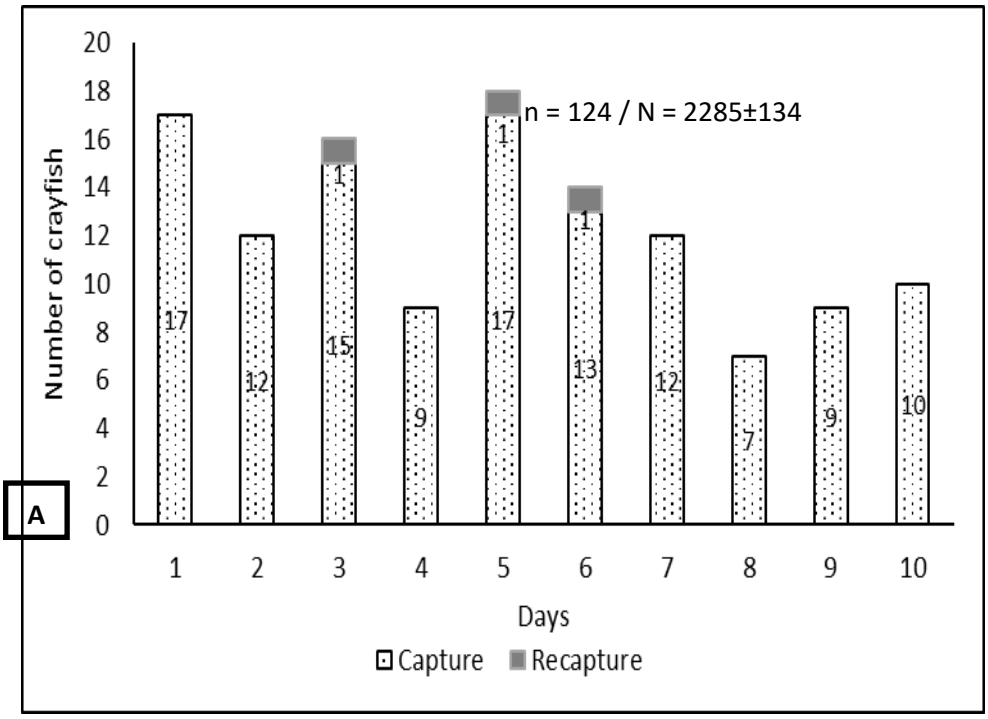
3. Results

The abundance of C. quadricarinatus. The results showed that *C. quadricarinatus* was indeed found in Lido Lake. The results showed an abundance of *C. quadricarinatus* had differences between each observation month. The abundance of *C. quadricarinatus* caught in each observation month is presented in Figure 4.

Sex ratio. Analysis of sex ratio is used to determine the ratio of the number of male and female crayfish. Sex ratios were then tested using Chi-square test to determine the condition of male and female freshwater crayfish in a population (Steel and Torie 1980).

$$\chi^2_{calc} = \sum \frac{(O_i - E_i)^2}{E_i} \; ; \; E_i = \frac{M+F}{2}$$

Random variable value or $\chi^2_{calculation}$ is the value that follows the distribution of Chi-square. O_i is the number of male (M) and female (F) crayfish observed, and E_i is the expected value of male and female crayfish. The hypotheses tested are:
H_0: The number of male and female balanced in water (1 : 1);
H_1: The number of male and female are not balanced in water (not 1 : 1),
while the decision rules used are as follows:
If $\chi^2_{calculation} > \chi^2_{table}$: reject H_0
If $\chi^2_{calculation} < \chi^2_{table}$: accept H_0



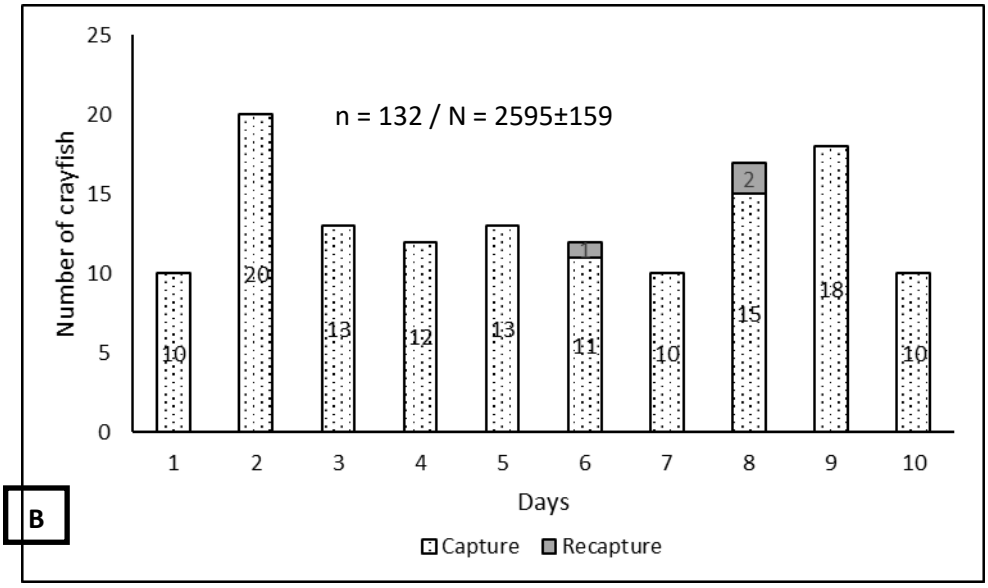


Figure 4. Amount (n) and estimate population abundance (N) of captured *C. quadricarinatus* for two sampling periods: A) October 2018 and B) February 2019

The results of observations on the sex ratio of *C. quadricarinatus* showed different values between two sampling periods. For 2 times of data collection, total obtained crayfish were 124 individual in October 2018 consisted of 61 males and 63 females crayfish while in February 2019, total 132 crayfish were caught consisting of 74 males, 57 females and 1 unidentified individual due to its very small size. Freshwater crayfish sex ratio based on periods time sampling are presented in Table 1 and 2. The chi-square test results showed that in two periods data sampling obtained sex ratio is 1: 1 and were found not significantly different at the 95% confidence interval.

C. quadricarinatus abundance and water quality. The results showed that the distribution pattern of *C. quadricarinatus* was random between observation stations. The abundance of *C. quadricarinatus* is related to the depth of the lake. Frequent caught of crayfish *C. quadricarinatus* was obtained at depths of 10 - 200 centimeters (cm). Complete data on *C. quadricarinatus* caught and water quality is presented in Table 3.

Table 1: The male-female sex ratio of *C.quadricarinatus* that catch during the observation period of October 2018

Days	*Total Catch*	*Male*	*Female*	*Sex Ratios*	$\chi_{Calculation}$ *Male*	$\chi_{Calculation}$ *Female*	$\chi_{Calculation}$	*Conclusion*
1	17	5	12	1 : 2.40	1.44	1.44	2.88	1 : 1
2	12	6	6	1 : 1.00	0.00	0.00	0.00	1 : 1
3	16	8	8	1 : 1.00	0.00	0.00	0.00	1 : 1
4	9	3	6	1 : 2.00	0.50	0.50	1.00	1 : 1
5	18	8	10	1 : 1.25	0.11	0.11	0.22	1 : 1
6	14	6	8	1 : 1.33	0.14	0.14	0.28	1 : 1
7	12	9	3	1 : 0.33	1.50	1.50	3.00	1 : 1
8	7	5	2	1 : 0.40	0.64	0.64	1.28	1 : 1
9	9	5	4	1 : 0.80	0.06	0.06	0.12	1 : 1
10	10	6	4	1 : 0.67	0.20	0.20	0.40	1 : 1
Total	124	61	63	1 : 1.03	0.02	0.02	0.04	1 : 1

Chi Squares (χ) Table : 3,84 (95% confident interval)

Table 2: The male-female sex ratio of *C.quadricarinatus* that catch during the observation period of February 2019

Days	*Total Catch*	*Male*	*Female*	*Sex Ratios*	$\chi_{Calculation}$ *Male*	$\chi_{Calculation}$ *Female*	$\chi_{Calculation}$	*Conclusion*
1	10	6	4	1 : 0.67	0.20	0.20	0.40	1 : 1
2	19	11	8	1 : 0.73	0.24	0.24	0.48	1 : 1
3	13	6	7	1 : 1.17	0.04	0.04	0.08	1 : 1
4	12	6	6	1 : 1.00	0.00	0.00	0.00	1 : 1
5	13	5	8	1 : 1.60	0.35	0.35	0.70	1 : 1
6	11	7	4	1 : 0.57	0.41	0.41	0.82	1 : 1
7	10	8	2	1 : 0.25	1.80	1.80	3.60	1 : 1
8	15	11	4	1 : 0.36	1.63	1.63	3.26	1 : 1
9	18	12	6	1 : 0.50	1.00	1.00	2.00	1 : 1
10	10	2	8	1 : 4.00	1.80	1.80	3.60	1 : 1
Total	131	74	57	1 : 0.77	1.10	1.10	2.20	1 : 1

Chi Squares (χ) Table : 3,84 (95% confident interval)

Discussion. Protection of biodiversity is an important thing related to the preservation of native ecosystems in an area. Indonesia as one of the countries with high biodiversity also plays an active role in protecting biodiversity. Indonesia's active role is demonstrated by ratifying the Convention United Nations Concern on Biodiversity and ratified the Cartagena Protocol on Biosafety. One of the invasive animals that are already on the list of invasive alien species is Australian Red Claw crayfish *C. quadricarinatus* (Parastacidae, Decapoda) (appendix No. 64 listed in the SK BKIPM No. 114 / KEP-BKIPM / 2017).

Several studies have shown that *C. quadricarinatus* has spread in Indonesian waters, including Maninjau Lake (Dina, 2012), Lido Lake, and Cilala Lake (Patoka et al., 2016). Strengthen the results of research Patoka et al., (2016), in this study, it was proven that *C. quadricarinatus* was found and obtained at Lido Lake, Bogor, West Java.

Table 3: *C. quadricarinatus* caught and water quality in each sampling point. SP: Sampling Point, FC: February Catch, T: temperature, Tr: Transparency, DO: Dissolved Oxygen, Al: Alkalinity

SP	*Latitude*	*Longitude*	*FC*	*TD (cm)*	*T (°C)*	*Tr (cm)*	*DO (ppm)*	*pH*	*Al (ppm)*
1	6°44'36.50'S	106°48'32.90'E	5	200	27.8	35	5.6	7.71	52
2	6°44'39.00'S	106°48'33.50'E	7	100	26.7	70	7.2	6.66	44
3	6°44'37.10'S	106°48'28.90'E	0	50	26.7	50	6.1	6.73	52
4	6°44'36.60'S	106°48'28.00'E	2	100	27.0	95	7.2	7.15	50
5	6°44'36.90'S	106°48'26.60'E	1	50	27.1	75	7.7	7.04	48
6	6°44'38.60'S	106°48'25.40'E	2	100	26.8	85	5.8	6.52	52
7	6°44'39.30'S	106°48'25.70'E	0	500	26.6	65	4.7	6.5	52
8	6°44'40.50'S	106°48'25.70'E	0	40	26.8	50	5.0	7.3	52
9	6°44'39.00'S	106°48'27.40'E	2	50	27.7	50	6.2	7.47	52
10	6°44'38.80'S	106°48'30.90'E	8	150	27.4	70	6.7	7.43	52
11	6°44'40.10'S	106°48'30.90'E	1	50	27.2	75	6.7	7.55	52
12	6°44'40.70'S	106°48'31.30'E	7	40	27.5	50	7.3	7.51	50
13	6°44'41.90'S	106°48'31.10'E	0	40	27.5	85	7.3	7.51	50

14	6°44′45.70′S	106°48′30.30′E	0	50	26.9	35	6.3	6.85	56
15	6°44′46.00′S	106°48′30.70′E	1	20	27.3	15	6.0	7.06	56
16	6°44′41.70′S	106°48′35.30′E	1	40	28.0	90	6.1	7.28	50
17	6°44′43.80′S	106°48′35.70′E	11	50	27.4	85	4.5	7.04	50
18	6°44′47.80′S	106°48′37.00′E	0	50	27.2	10	6.0	6.97	48
19	6°44′44.00′S	106°48′38.00′E	2	30	27.1	50	6.0	6.94	50
20	6°44′42.10′S	106°48′37.80′E	1	50	27.4	50	6.1	7.22	48
21	6°44′41.80′S	106°48′38.20′E	0	10	27.2	50	6.2	7.19	50
22	6°44′41.20′S	106°48′38.60′E	2	40	27.2	50	6.2	7.19	50
23	6°44′40.90′S	106°48′37.70′E	9	50	27.2	30	5.1	7.34	48
24	6°44′40.40′S	106°48′37.00′E	1	50	27.2	50	5.1	7.34	48
25	6°44′39.90′S	106°48′36.50′E	4	50	27.7	40	7.0	7.43	52
26	6°44′38.50′S	106°48′36.80′E	3	40	27.7	50	7.0	7.43	52
27	6°44′37.70′S	106°48′36.40′E	3	20	27.7	50	7.0	7.43	52
28	6°44′37.00′S	106°48′35.60′E	4	10	28.4	50	6.4	7.6	52
29	6°44′36.10′S	106°48′36.00′E	1	50	28.2	50	6.6	7.66	52
30	6°44′35.30′S	106°48′36.70′E	0	50	28.1	50	6.1	7.36	52
31	6°44′35.60′S	106°48′37.80′E	0	50	28.1	50	6.1	7.36	52
32	6°44′37.80′S	106°48′39.40′E	0	30	28.8	30	8.5	7.23	48
33	6°44′37.90′S	106°48′40.20′E	2	50	28.8	50	8.5	7.23	48
34	6°44′37.30′S	106°48′39.90′E	2	50	28.0	50	6.6	7.42	48
35	6°44′35.50′S	106°48′39.20′E	0	50	27.5	50	7.3	7.55	48
36	6°44′34.00′S	106°48′38.10′E	11	30	27.5	30	7.3	7.55	48
37	6°44′33.40′S	106°48′38.70′E	12	30	27.5	30	7.3	7.55	48
38	6°44′33.20′S	106°48′39.40′E	2	30	27.5	30	7.3	7.55	48
39	6°44′29.50′S	106°48′37.40′E	0	100	28.1	100	5.1	6.97	48
40	6°44′31.60′S	106°48′42.70′E	0	50	28.1	50	5.1	6.97	48
41	6°44′33.00′S	106°48′43.80′E	5	30	27.7	30	4.9	6.73	48
42	6°44′28.90′S	106°48′47.00′E	11	50	27.7	40	4.9	6.73	48
43	6°44′29.60′S	106°48′37.40′E	1	10	28.0	30	5.1	6.81	44
44	6°44′30.40′S	106°48′41.20′E	2	15	27.6	50	6.5	6.92	48
45	6°44′30.60′S	106°48′41.30′E	0	40	27.6	30	6.5	6.92	48
46	6°44′43.40′S	106°48′31.40′E	5	20	28.0	50	7.9	7.47	52
47	6°44′35.30′S	106°48′34.40′E	1	30	27.7	30	6.8	7.68	52

The results showed that *C. quadricarinatus* can be found both in the transitional season (October) and the wet season (February). This implies that the abundance of *C. quadricarinatus* in Lido Lake is high enough to be obtained throughout the season. This is supported by the results of Zeng (2018) research which shows the spread of *C. quadricarinatus* has covered eight locations of water bodies in Indonesia and is easily available in all seasons. The high abundance of *C. quadricarinatus* due to tropical waters is suitable for developing and reproducing *C. quadricarinatus*. This is consistent with the observation of Belle & Yeo (2010) that *C. quadricarinatus* is easy to breed in tropical climate countries such as Singapore.

The highest abundance of *C. quadricarinatus* was obtained in February 2019 (wet season) compared to October 2018 (transitional season). It is suspected that in February it is the peak of the wet season thus providing comfortable conditions for *C. quadricarinatus*. Besides, the highest abundance of *C. quadricarinatus* in February is thought to be due to the wet season, the food of *C. quadricarinatus* is relatively more abundant than in the transitional season.
The sex ratio of *C. quadricarinatus* at Lido Lake based on the Chi-square test, the condition is balanced. A similar study with the condition of male and female *C quadricarinatus* was balanced which is located on Maninjau Lake (Dina 2012) and previous study at Lido Lake (Ramadhani, 2018). The balanced condition of males and females can be caused by favorable environmental conditions (temperature, pH, DO, food availability, and alkalinity). According to Effendie (2002), 3 factors influence the crayfish sex ratio: differences in behavior patterns, differences in mortality rates, and growth rates of male and female crayfish. Changes in the different sex ratios are thought to be related to the reproductive activity of *C. quadricarinatus*. Reynolds (2002) stated that the number of female crayfish caught will decrease during the mating season because of the different activities and ability to catch female crayfish in the crayfish mating season. Crayfish females are laying eggs or are in the conditions of incubating relatively few active eggs and hiding in holes or hiding under rocks (Arias et al., 2012). The number of *C. quadricarinatus* females incubating eggs and hiding results in the number of *C. quadricarinatus* males caught, ultimately resulting in differences in the ratio of females caught.

Frequent caught of crayfish *C. quadricarinatus* in Lido Lake was obtained at the depth of lake waters 10 – 200 cm. It is suspected that this depth is the favorable depth for *C. quadricarinatus*. This result is similart to Nurhafidzoh (2018) who found crayfish habitat at depth between 0 - 300 cm. It is probably related to food availability and oxic condition as seen in Table 3. In general, the food of C. quadricarinatus are some types of snails, fruits fall, aquatic plants (Pavasovic et al., 2007), benthic micro- and meiofauna, and decaying organic material (Cabi, 2019).

Water quality at each observation station shows a uniform pattern. Generally, water temperature ranges from 26.7–28.7^{o}C, pH ranges from 6.52-7.71, DO ranges from 4.5-8.5 ppm, and alkalinity ranges from 44-56 ppm. Transparency at Lido lake waters has a high value. These aquatic parameters value indicate optimum condition for growth and development of *C. quadricarinatus* as noted in CABI (2019).

Ovigerous female and juvenile of the crayfish were found (Figure 5). This finding indicates that *C. quadricarinatus* has been able to adapt, breed and become established in Lido Lake. Its occurrence in the lake's wide area also strengthens the fact that this species has become invasive species in the ecosystem. Future tasks would reveal the possible impact of its presence on other native crustaceans in the lake.

A.  **B**. 

Figure 5. Ovigerous female (A) and juvenile (B), indicating well-established population of *C. quadricarinatus* in Lido Lake, West Java – Indonesia.

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