Conservation of the critically endangered and endemic shrimp *Caridina linduensis* in Lake Lindu, Central Sulawesi, Indonesia

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Progress Report
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Yayasan Aksi Konservasi Celebica

By:

Diky Dwiyanto, Auni Ade Putri, Muh. Herjayanto

صندوق محمد بن زايد
للمحافظة على الكائنات الحية
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INTRODUCTION

A. Background

Freshwater ecosystem provides various critical support for live, not only for human live but also a large number of plants and animals. Although fresh waters consist of only 0.01% of the water on Earth, they host many unique and endemic creatures, including freshwater plants, fishes, birds, reptiles and invertebrates (Reid *et al.* 2019). In Sulawesi, largest tropical island in Wallacea region, freshwater habitat includes streams, rivers, creeks, natural pond and lakes. Three lakes in Sulawesi have been proposed as an ancient lakes, i.e. Lake Poso, Malili Lake System and Lake Lindu, but only the first two lakes are clearly ancient based on their estimated age and their fauna (von Rintelen *et al.* 2012). The age of Lake Lindu is relatively young compared to Lake Poso and Malili Lake System. However, they are home to various freshwater species including endemic fishes, mollusk, crab and shrimps (Roux, 1904; Parenti, 2008; Annawaty *et al.* 2016).

Lake Lindu located between 120°02'–120°06' E and 01°16'–01°21' S in Central Sulawesi highlands become uplifted during Pliocene to Pleistocene (~4 Mya) (see Nugraha and Hall, 2018). Nowdays, Lake Lindu is the highest lake in Sulawesi with an altitude up to 900 m above sea level. The deepest basin of Lake Lindu has a maximum depth approx. 72.6 m (Lukman, 2007). Lake Lindu was formed due to tectonic activity which came from the movement of three major tectonic plate, i.e. Pacific, Indo-Australia and Eurasia and now becoming Palu-Koro Fault. With an area 34.5 km^2, this lake is the largest freshwater ecosystem in Lore Lindu National Park, Central Sulawesi, Indonesia. In 1978, Lake Lindu was considered as a tourism forest or Hutan Wisata Danau Lindu by the Ministry of Agriculture (No. 46/Kpts/Um/1/78) and become an enclave area of Lore Lindu National Park (Taman Nasional Lore Lindu or TNLL) in October, 5th 1993 through the second instruction letter of the Minister of Forestry (No. 593/Kpts-II/1993). Most part of this lake is surrounded by protected forest and several mountains, namely Mt. Nokilalaki (2,357 m), Mt. Lantawungu (2,270) and Mt. Tumawu (2,192) (Lukman, 2007).

Lake Lindu fauna was firstly introduced by Paul Benedict Sarasin and Fritz Sarasin who documented their expedition during in Sulawesi in a book entitled "Reisen in Celebes" published in 1905. These specimens comprise fish (Popta, 1905), crab (Roux, 1904) and shrimp genus *Caridina* (Roux, 1904). After the last expedition in the lake made by two Entomologist, C. Bonne dan J. Bonne-Wepster, in 1939, for several decades, no further research on the lakes was conducted. In 2011, new fieldwork was made in the lakes by Annawaty and Wowor (2015) and described two new species, *C. dali* and *C. kaili*. Several aspects for their ecology and habitat preferences also have been studied (Annawaty *et al.* 2016). *Caridina linduensis* Roux, 1904 is one of the freshwater shrimp endemic to Lake Lindu that has been almost one century ago after their first description. The last survey of this species was found the highest number for their population only up to 21 individuals (in Uwe Rawa or outlet) (Annawaty *et al.* 2016). However, the exact population size of *C. linduensis* has never been studied. Annawaty *et al.* (2016) also mentioned the presence of one alien invasive prawn, *Macrobrachium lanchesteri* (de Man, 1911), which growing so fast in the lake only for several years (Pers. Observation 2018). Another anthropogenic activities in lake, such as land conversion, habitat destruction and pollution both from agricultural runoff, transportation activities from boat and settlement (De Grave and Wowor, 2020) can also potentially harm the population of *C. linduensis* in Lake Lindu.

B. Aims and Objectives

The aims of the project are to provide the first assessment on the population of *Caridina linduensis* and conservation efforts to maintain their population.

The objectives of the project are the following:

1. To assess their population density, population structure, and breeding season;
2. To determine the life history of *Caridina linduensis*;
3. To provide a conservation strategy based on multiple approaches including build an artificial and protected spawning ground and initiate an education program involving the local community/NGO.

METHODS

A. Project Site and Time

Lake Lindu is located in the Sigi Regency, Central Sulawesi, Indonesia. This lake belong to an enclave area of Lore Lindu National Park, the largest protected area in Central Sulawesi that designated in 1993. Administratively, Lake Lindu belongs to Lindu Sub-district comprised five villages, i.e. Puro'o, Langko, Tomado, Anca and Olu. There are eight streams that flows into the lake (inlet), including Lembosa, Tokaranu, Salusuo, Kalamoa, Bomba, Bose, Langko, Dongi and several other small streams. Lake Lindu is drained by the Rawa River which is the only outlet of this lake that flows into the Gumbasa River and join with the Palu River.

The project was started by conducting a preliminary survei on June, 5–6 2022 in several sites. After that, the sampling of *Caridina linduensis* on the lake was conducted on June, 10–12 2022, July, 22–25 2022 and September, 28–30 2022. Four sites were sampled during the fieldwork in Lake Lindu (Uwe Rawa, Anca, Langko and Pulau Bola). We selected these sites based on previous study done by Annawaty and Wowor (2015) who reported the locality of *Caridina linduensis*. These sites mostly located in the south and southwestern of the lake.

Uwe Rawa (Outlet) (Lat. 01°16'24.44" S, Long. 120°06'29.14" E; Elev. 963 m)

Uwe Rawa or Rawa River (Uwe=River) is located in the northern part of Lake Lindu which is the outlet of this lake that flows towards the north and at a point turns left to join the Sopu River and then Gumbasa River. This river is approx. 81.42 m in width and become narrow. The water flows through three waterfalls, about 40 m in height before join the Sopu River. The water current is ranging from slow to moderate with water depth about 0.55–0.80 m. The area is covered by secondary forest and open area for plantation. There is one gazebo and jetty that used by local people when come to this area. This area is used to one of the recreation site. Some parts of this area also have been detected containing focus site for Schistosomiasis. There are many waterplant (ferns) along the riverbank which is good habitat for freshwater fauna. The substrate is coarse sand, peeble and leaf litter.

Figure 1 Secondary forest around Uwe Rawa

Figure 2 Uwe Rawa, the outlet of Lake Lindu

Anca (Lat. 01°19'31.60" S, Long. 120°03'09.79" E; Elev. 980 m)

Anca is a village located in the western side of Lake Lindu. The area including local community sattlement, rice field and also buffalo herding. Many native waterplant can be found in the shore of the lake in this area (Dali in local language). This area is a shallow water, made up of open, treeless landscapes along lakeshores. The local community uses several sites as rest stops en route to the plantation. The substrate is coarse sand with water depth ranging about 0.20–0.30 m.

Figure 3 Water plant in the shallow water near Anca

Figure 4 Water buffalo grazing on the shore of the lake

Langko (Lat. 01°20'46.33" S, Long. 120°03'36.09" E; Elev. 951 m)

Langko is located in the south part of Lake Lindu, near Langko Village. At this site, there is a fish hatchery or Balai Benih Ikan (BBI), managed by the Ministry of Fisheries, Indonesia. The introduced fishes, such as Nile and Mozambique Tilapia, were regurarly re-stocked in the lake from this hatchery. This site is also consist of open area with water plant (mostly ferns) in the shore of the lake. The local fisherman also keeps their boats in this area after came back from catching the fishes. There is also water buffalo and horse grazing in the grassland near the BBI, approx. 50 m from the shoreline. The water depth is about 90–100 m with muddy substrate.

Figure 5 Balai Benih Ikan in Langko

Figure 6 Ferns and dali in Lake Lindu

Pulau Bola (Bola Island) (Lat. 01°20'54.53" S, Long. 120°04'02.27" E; Elev. 984 m)

Pulau Bola is a small island in the south part of Lake Lindu. This island comprises the secondary forest and cacao plantation. There is a jetty on this island that used by the local people to visit an old grave in the middle of this island. The local community also visit this island for fishing and hunting. The shore of the lake composed by secondary forest and many waterplant along the shoreline. The water depth is ranging 0.99–1.0 m with muddy sand substrates.

Figure 7 Secondary forest in Pulau Bola

Figure 8 The waterplants in the shoreline

B. Data Collection and Reared Specimens

Data on the population of *Caridina linduensis* was collected using a tray net 62 × 50 cm (mesh size about 0.5 mm). The samples were captured using kick and push method (Dwiyanto *et al.* 2018) in the microhabitat of *C. linduensis*, such as waterplants, leaf litter, and dead wood. We sampled for 30 min (catches per unit effort, CPUE) (Schoolmann & Arndt, 2018) over a distance of approximately 50 m for each site. We used boat for visiting the each site. Each locations comprises three sites for represent repetitions. We also tried to collect the shrimps in Tomado (in front of the cottage) which reported as one of the locality of *C. linduensis* (Annawaty & Wowor, 2015) but failed to get the specimens. The samples were measured for their carapace length (cl) and barried females (ovigerous female) were recorded.

All observed specimens were released back in their habitat to keep their population. In this project, we did not preserved the specimens except fot two individuals that photographed for documentation. Since in the study of the population of endangered species scientist was usually collecting the specimens as much as possible to know their exact population size, collecting and then preserved the specimens in alcohol might contribute to reduce their population in the wild. Measurements of physicochemical parameters of water at the different sampling locations, including water temperature, dissolved oxygen, pH, conductivity and electrical conductivity (EC) were done using a multiparameter device and DO meter

A total of 30 specimens were kept alive using a small tank. They were packed using plastic bag and the oxygen was supplied by a portable aerator. These specimens were transported to the Laboratory of Animal Biosystematic and Evolution, Department of Biology, Tadulako University in Palu, Central Sulawesi, Indonesia. They were reared in the laboratory in the tank. The larvae of *C. linduensis* was collected every day and then preserved in a 1,5 ml tube and fixed in 96% alcohol.

RESULTS

A. Fieldwork to Lake Lindu

The water temperatures at Lake Lindu, Central Sulawesi, relatively higher ranged from 25.5°C to 29.3°C compared to small streams around the lake ranged from 21°C to 22.3°C. Dissolved oxygen (DO) ranged from 4.9 mg/L to 18 mg/L with pH ranging from 7.06 to 7.66. The water conductivity at this lake was relatively low ranging from 63 to 75 µS/cm with a total dissolved solid (TDS) ranging from 30 to 36 ppm. Data on the water temperature in this project was almost the same as Annawaty *et al.* (2016) who carried out the research at this lake in 2011 and found that the water temperature ranged from 28°C to 29°C.

Figure 9 Sampling *C. linduensis*

Figure 10 Measuring the carapace length

Figure 11 Measuring the water parameter

A total of **296** of *C. linduensis* were recorded during the sampling period. The samples comprises 103 ind. male and 193 ind. female with mean density **7 ± 9 ind. CPUE^{-1}**. The sex ratio in the population was **1 ♂ : 2 ♀** during the sampling period. The carapace lengths (cl) of *C. linduensis* male and females ranged between **2.20–3.80 mm** and **3.53–4.70 mm**, respectively. The total length (tl) of *C. linduensis* male and female ranged between **11.5–13.2** mm and **13.2–15.0** mm, respectively.

Analysis of the population size of *C. linduensis* in the Lake Lindu showed significantly highest abundances on Uwe Rawa region compared to other locations (Fig. 12). We found a higher number of *C. linduensis* in Uwe Rawa (see Fig. 2) compared to Annawaty *et al.* (2016) who only collected 21 individuals. The result of this project showed that Uwe Rawa provides many good habitats for this species, thus potentially to developed as a protecting site.

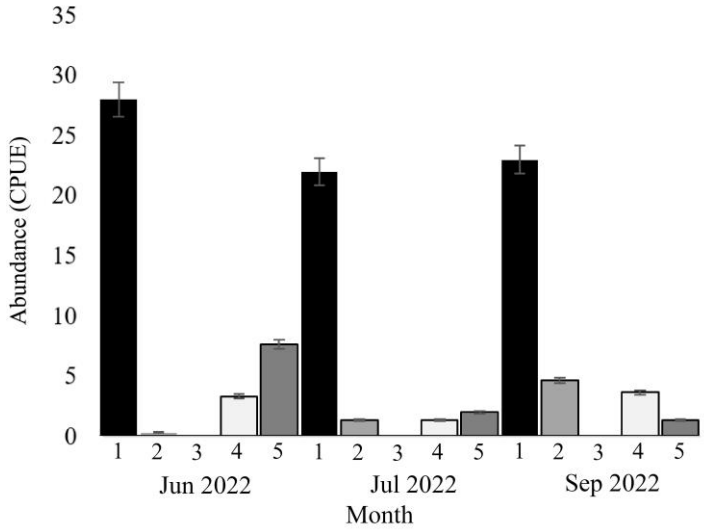

Figure 12 Abundance of *C. linduensis* in each sampling locations in the Lake Lindu. (1) Uwe Rawa; (2) Anca; (3) Tomado; (4) Langko; (5) Pulau Bola.

B. Breeding Program

A total of 30 adult shrimp including 6 ovigerous female of *C. linduensis* were kept in the tank to know their reproductive biology or life history. The samples were reared in four tanks, i.e. two large tanks each containing 10 ind. and two small tanks each with 5 ind. The eggs hatched in 7 days after collected. The number of larvae ranged from **13 to 24** individuals. To know the duration from spawning to hatched under the laboratory conditions, we kept the female and male into one tank. The eggs hatched in **19–22 days** after spawning. This result showed that *C. linduensis* has a shorter duration of hatch eggs than another land-locked species, such as *C. formosae* which hatched 34–37 days after spawning (Shy *et al.* 2001). The survival rate of *C. linduensis* was **40–56%**. The larvae was successfully reared until more than 60 days. For each day, two ind. were collected and then preserved for further drawing and description.

Figure 13 Monitoring the larval development

Figure 14 Larvae of *C. linduensis*

Conservation Program

We started the education program by bring together head of sub-district (Camat Lindu) and head of villages. During the meeting, we discussed about this project and many problems faced by endemic species in Lake Lindu and how the local community can participate to save their nature. After that, we carried out the education program involving the local community in Langko Village and mini workshop on monitoring the population of *Caridina sulawesi* to the young people in Lake Lindu.

First, we showed a 30 minute presentation to introduce the endemic fauna containing slides of aquatic endemic fauna of Lake Lindu. We then asked questions related to the presentation to the participants. The presentation and discussion sessions lasted for two hours, from 3.30 to 5.30 pm. A total of 25 people participated in this program. After the presentation, we shared a snack made from invasive prawn, *Macrobrachium lanchesteri* to the participants, i.e meatball (we called it Bakso Udang) and prawn noodle (or Mie Udang). We then asked the questions related to the taste of the snacks. There were mixed responses from the participants, from scared to consumed, excited, and enthusiastic. After finishing the snack, we explained the important to reduce the population of this invasive species by using them as a food. Furthermore, we also provide the recipe for the participants and ask them to made it in their home.

The second program was capacity building for the young local people in Lake Lindu. We invited one of the freshwater shrimp expert from National Research and Innovation Agency (BRIN), Dr. Daisy Wowor, to giving the workshop on collecting and monitoring freshwater shrimp population in Lake Lindu. A total of five young local people were involved in this program.

Another ongoing conservation program was to provide a signboard in the habitat of *C. linduensis*. We used a metal rectangle and placed a poster in Bahasa Indonesia to give the information for the local community around the lake. This signboard will be installed in the one location where the highest population density was found.

Figure 16 Seminar on introduction to the endemic fauna of Lake Lindu

Figure 15 The participants trying the snacks

Figure 17 Mini workshop on monitoring shrimp population by Dr. Daisy Wowor

Figure 18 Design of signboard

Figure 19 *Caridina linduensis* from Lake Lindu

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