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Original research

Habitat Preferences and Distribution of the Freshwater Shrimps of the Genus *Caridina* (Crustacea: Decapoda: Atyidae) in Lake Lindu, Sulawesi, Indonesia

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ABSTRACT

The objectives of this study were to reveal ecological preferences and distribution of all species of *Caridina* found in Lake Lindu and their catchment area. Specimens from 39 sampling sites were caught using tray net and hand net. There are three species of *Caridina* found in the lake system, i.e. *Caridina linduensis* (Roux 1904); *Caridina kaili* (Annawaty & Wowor 2015) and *Caridina dali* (Annawaty & Wowor 2015). There is no overlapping distribution among the species. *C. kaili* is a true riverine species and it is never encountered sympatric with *C. dali* nor *C. linduensis*. This species is abundant in streams and ditches with moderate flow running water and gravel–cobble substrate. It is mainly spread within streams west to the lake. Both *C. dali* and *C. linduensis* can be found in the lake and streams with very slow current to almost stagnant water, muddy sand substrate and associated with roots of water plants and leaf litter. However, *C. dali* is never occurred together with *C. linduensis* and they are less abundant compare to *C. kaili*. Distribution of *Caridina* spp. in Lake Lindu is probably affected by the temperature of their habitats and the occurrence of introduced fish such as Mozambique tilapia (*Oreochromis mossambicus*), common carp (*Cyprinus carpio*), and an alien riceland prawn (*Macrobrachium lanchesteri*). These introduced and alien species can have the potency to become predators or competitors for the *Caridina* spp. It is also the first record for *M. lanchesteri* present in Lake Lindu.

1. Introduction

Fresh water atyid shrimps are widely distributed in Indonesia. They can be found in various water bodies such as lake, pond, river, stream and ditch, both in surface and underground waters (Wowor *et al.* 2004). The shrimps are characterized by having chelipeds with setae on the tip of the fingers which are used for filtering small aquatic organisms or scraping detritus during feeding (Fryer 1977). The family Atyidae consisted of 469 species, a majority of them belonging to the genus *Caridina*. This genus has 290 species members (De Grave & Fransen 2011). In Indonesia, there are 62 species of atyid shrimps and 52 are reported to be found in Sulawesi and nearby islands (Roux 1904; Cai & Ng 2005; Zitzler & Cai 2006; Cai & Wowor 2007; Klotz *et al.* 2007; von Rintelen *et al.* 2008; von Rintelen & Cai 2009; Cai & Ng 2009; Cai *et al.* 2009; De Grave & Fransen 2011; Klotz & von Rintelen 2013). The majority of the species are lacustrine *Caridina* which are endemic to the island.

In the last 10 years, the study of the lacustrine *Caridina* spp. in Sulawesi has been focused in taxonomy and evolution of the species. The studied lakes are Poso and Malili lake systems which were considered by Schön & Martens (2004) as ancient lakes. Recently, the ancient status of the lakes was confirmed both in terms of their estimated age as well as their fauna (von Rintelen *et al.* 2012). In agreement with the definition of ancient lake which is usually perceived as more or less long-lived lake that was often associated with both high species numbers and endemicity in various systematic groups (Albrecht 2012).

The taxonomy and the evolution of the *Caridina* spp. in the 2 ancient lake systems of Sulawesi have been studied for more than a decade; on the contrary, Lake Lindu, a putatively ancient lake in

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Sulawesi, was almost neglected for more than a century. *Caridina linduensis* was the only atyid shrimp reported from the lake and only recently two more species are encountered, i.e. *Caridina kaili* and *Caridina dali* (Annawaty & Wowor 2015). These two new species increase the total number of *Caridina* spp. in the lake system to three times as high as previously reported.

The *Caridina* spp. from the lake occupy different habitats and have specific distribution pattern. Therefore, to reveal the habitat preferences and to map the distribution of the *Caridina* spp. in Lake Lindu and its catchment area became the objectives of this study.

2. Materials and Methods

2.1. Study area

The Lake Lindu system (01°16′–01°23′ S, 120°1′–120°11′ E) is located in the Lindu enclave in Lore Lindu National Park, Sulawesi (previously Celebes), Indonesia. This relatively small lake covered an area of 34.5 km^2 with 72.6 m maximum depth, drain to the north *via* Rawa River, the only outlet for Lake Lindu, to Palu Bay (Lukman 2007). The lake is fed by several streams from its catchment area, where 83.3% of the catchment area belongs to the Lore Lindu National Park. However, generally the gentle sloped eastern part and several small parts in the western sites of the lake have been converted into agricultural land. Most of the converted land has been turned into rice fields and cacao plantations. The study area was divided into four, i.e. north, east, south and west area. Uwe is Kaili dialect of Central Sulawesi for stream.

2.2. Collecting specimen

Purposive sampling method was applied in 39 sampling sites (Figure 1). Samples were collected with tray net and hand net in July, August and November 2011. All specimens obtained were fixed in 96% ethanol. The ethanol was changed after 24 hours with fresh 96% ethanol. The specimens are deposited in Division of Zoology, Research Center for Biology, Indonesian Institute of Sciences (LIPI), Cibinong and Laboratory of Molecular, Division of Animal Function and Behavior, Department of Biology, Bogor Agricultural University, Bogor, Indonesia.

The habitat parameters recorded were (1) temperature of water, (2) qualitative water clarity, (3) qualitative water current (slow current water to almost stagnant or moderate flow), (4) substrate (sediment classification) based on Wentworth (1922), (5) presence or absence of water plant associated with the *Caridina* habitat, and (6) coordinate and altitude of sampling locations by using Global Positioning System.

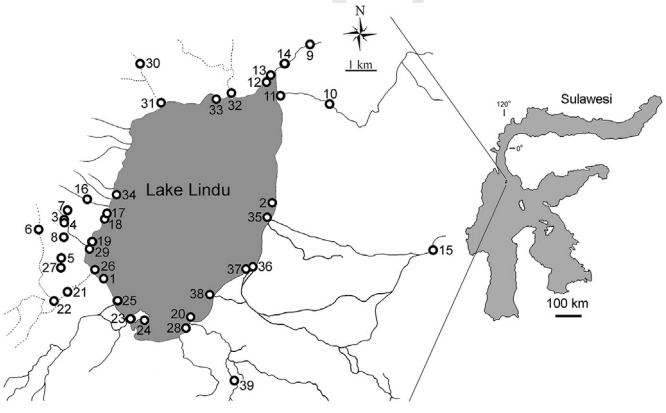

Figure 1. Location of the Lake Lindu System in Sulawesi Island (right) and overview of the sampling sites in the lake (left). Circle refer to the sampling site.

2.3. Data analysis

The data of coordinate and altitude of sampling location were overlaid to the map of Lake Lindu system published by Badan Informasi Geospasial. The percentage of each species of *Caridina* found was measured by the amount of particularly species caught to the total of *Caridina* caught.

3. Results

A total of 1743 specimens of *Caridina* were obtained. They were consisted of 89.4% *C. kaili*, 7.5% *C. dali* and 3.0% *C. linduensis*. From the 39 sampled sites, only 21 sites were inhabited by *Caridina* spp. *C. kaili* was the most common species and it was found in 11 sites, while *C. dali* and *C. linduensis* were only obtained from six and four sites, respectively. Water temperature of the lake and its catchment area was ranged between 18°C and 29°C, and the altitude ranged between 982 and 1020 m (Table 1).

Distribution of the species of *Caridina* in Lake Lindu and the catchment area showed there is no overlapping among the species. *C. linduensis* is never found in sympatry with *C. kaili* as well as *C. dali*. The species was found both in lake and the outlet of the lake with small amount of specimen. There are only three sites in the lake where *C. linduensis* are present and one site in the outlet (Figure 1). For the outlet population, the species dwell in the shore of the river with very slow current or almost stagnant. Even though this species was never found in sympatry with the other species of *Caridina*, however four specimens of *C. linduensis* were found together with riceland prawn, *Macrobrachium lanchesteri* in Tomado beach at cottage of Festival Danau Lindu (FDL).

C. kaili, the true riverine species only inhabit the stream or ditch with moderate flow running water (Figure 2). Most of the species are disperse in the stream and ditch in western part of the lake, and only found in two streams in the eastern part of the lake, i.e. Uwe Tokaroru and Uwe Lembosa.

C. dali is only distributed in the eastern part of the lake, particularly near the mouth of the inlet stream (Figure 2). The species were found not only in the lake but also in a stream with slow current in eastern part (Kati stream). The sympatry with *M. lanchesteri* also establish in population of *C. dali* in the western mouth of Uwe Kati.

4. Discussion

Only three species of *Caridina* were found in the Lake Lindu system which is less in number compared to the other two ancient lake systems in Sulawesi, i.e. Lake Poso (six species) and Malili Lakes system (15 species) (Von Rintelen & Cai 2009). *C. kaili* was found in large numbers in both western and eastern parts of the lake system. The high abundance of the shrimp is related to the large amount of accumulated vegetation debris on the bottom of the stream which in turn provides food sources for the shrimp (Bentes *et al.* 2011). The majority of streams in western and eastern part surrounded by dense primary forest belong to the Lore Lindu National Park.

In addition, *C. kaili* have very short rostrum, the shortest rostrum among the species of *Caridina* in the lake system. Other Sulawesi atyids such as *Atyopsis spinipes, Caridina sulawesi, Caridina leclersi* and *Caridina parvidentata* have short rostum too. They are inhabitants of fast flow running water as showed by other atyids outside Sulawesi (Felgenhauer & Abele 1983; Hartoto & Wowor 1986). The short rostrum shape is suitable for inhabiting moderate to fast flow running water because it reduces frictional resistance of the oncoming current (Felgenhauer & Abele 1983).

The high abundance of *C. kaili* in streams and ditches demonstrates the favorable habitat of the species. The large mass of

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