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Original Article

Species diversity of rotifers (Rotifera: Eurotatoria) of Phu Ninh Lake with five new records from Vietnam

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Abstract: A total of sixty-one taxa of rotifer, belonging to 15 families, 3 orders were identified from the Phu Ninh Lake, Vietnam. Of these, five species were recorded new to Vietnam Rotifera fauna, including *Lecane acanthinula* (Hauer, 1938), *L. sola* (Hauer, 1936), *L. thailandensis* Segers & Sanoamuang, 1994, *L. pyriformis* (Daday, 1905), and *Mytilina bisulcata* (Lucks, 1912). The result raised the total number of rotifers known from Vietnam to 227 species. Moreover, the results showed that the number of species recorded increased with the increase of sample size, which followed the equation $y=12.85+14.12\log(x)$ ($R^2=0.99$). Based on the estimators, the α -diversity of rotifers in Phu Ninh Lake might be up to 67 ± 4 taxa (according to the Bootstrap index), 71 ± 8 taxa (according to the Chao index), or even up to 79 taxa (according to Jackknife 2 index).

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Introduction

Rotifera is widely distributed in inland aquatic habitats playing an important role in freshwater ecosystem functioning. Moreover, they can be used as indicators of water quality (Sládeček, 1983), toxicology test organisms (Arnold et al., 2011), and live feeds for fish larvae in aquaculture (Lubzens, 1987; Ogata and Kurokura, 2011). Although rotifer has such great roles, the knowledge of rotifer diversity in Vietnam is still poor (Trinh-Dang et al., 2013, 2015). The first record of rotifer diversity in Vietnam was reported by Shirota (1966) with 63 species in fresh and saline water environments. Dang et al. (1980) recorded 52 species of rotifer in freshwater bodies in South Vietnam. The number of rotifer species recorded by a few studies after that were 65 species in Central Vietnam (Zhdanova, 2011) and 49 species in South Vietnam (Phan and Le, 2012). Most notably, the recent studies conducted by Trinh-Dang et al. (2013, 2015) documented one hundred new record and four new species for Vietnam rotifers fauna in freshwater bodies of the Thua Thien Hue Province indicating the high potential of rotifer diversity in

Vietnam. In order to contribute more knowledge on rotifers diversity for Vietnam, we conducted the study on species diversity of Rotifera of the Phu Ninh Lake, the largest reservoir in the Central of Vietnam, which plays an important role for supplying water and regulating climate to the Central of Vietnam.

Materials and Methods

The Phu Ninh Lake is a mesotrophic lake situated in Northern Quang Nam Province with a surface area of 23,409 ha (Fig. 1). Thirty plankton samples were collected in rainy season (December 2017) and dry season (April 2018). Qualitative samples of rotifers were collected using a 50 μm mesh size cast-net and then preserved in 4% formaldehyde. Rotifer specimens were sorted and examined using a Hund (H600) compound microscope equipped with a camera. The trophi of rotifers was examined by adding a drop of commercial sodium-hypochloride (NaOCl) to dissolve and isolate the hard trophi parts.

The species accumulator and species richness estimators were calculated using the *vegan* package (Oksanen et al., 2013) in R program (R Development

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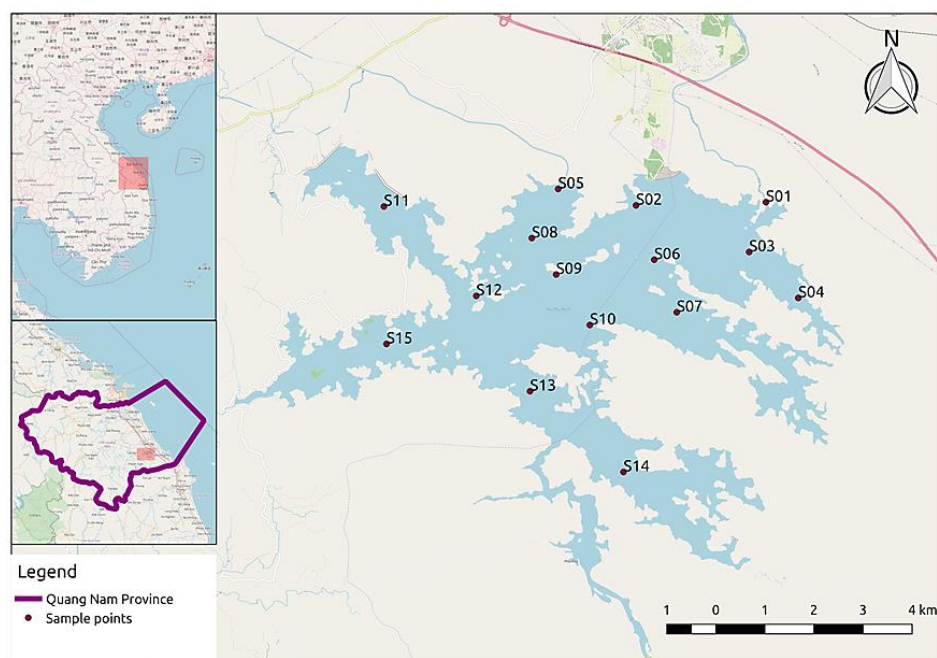


Figure 1. Schematic map of the study area at Phu Ninh Lake.

Core Team, 2018). Of these, Jackknife 2 (Eq. I) and Chao 2 (Eq. II) estimators were selected to estimate the expected diversity of rotifer in Phu Ninh Lake, as the following formulas:

$$Jack_2 = S_0 + f_1 \frac{2N-3}{N} - f_2 \frac{(N-2)^2}{N(N-1)} \quad (\text{Equation I; Smith and van Belle, 1984})$$

$$Chao_2 = S_0 + \left(\frac{N-1}{N} \right) \left(\frac{f_1(f_1-1)^2}{2(f_2+1)} \right) \quad (\text{Equation II; Chao, 1987})$$

Where: S_0 = observed number of species in the pooled samples series, f_1 = number of singletons; f_2 = number of doubletons, and N = total number of samples.

Results

Species composition: A total of sixty-one taxa of rotifer, belonging to 15 families, and 3 orders were identified from the Phu Ninh Lake (Table 1). Of these, five species were recorded new to Vietnam rotifera fauna, including *Lecane acanthinula* (Hauer, 1938), *L. sola* (Hauer, 1936), *L. thailandensis* Segers & Sanoamuang, 1994, *L. pyriformis* (Daday, 1905), and *Mytilina bisulcata* (Lucks, 1912) (Table 1; Figs. 2-6). Of the total 15 families recorded in the Phu Ninh Lake, the most diverse family was Lecanidae (18 taxa, 29.51%), followed by Brachionidae (14 taxa, 22.95%),

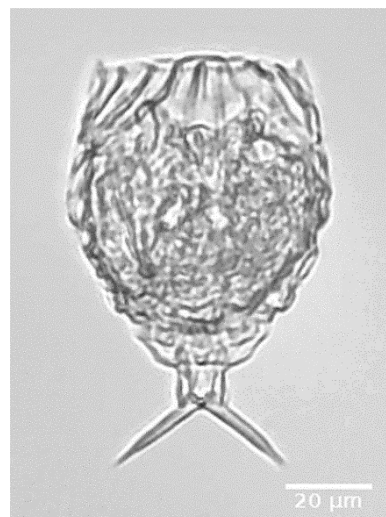


Figure 2. *Lecane sola* Hauer, 1936, habitus - dorsal view.

Trichocercidae (4 taxa, 6.56%) and Synchaetidae (4 taxa, 6.56%). Four families viz. Collotheceidae, Hexarthridae, Testudinellidae, and Asplanchnidae were present in single species (Fig. 7).

Species richness: The number of taxa recorded in the dry season (59 taxa) was higher than that of rainy season (37 taxa). The taxonomic species composition markedly differed between the two seasons. Lecanidae was the most diverse family in the dry season with 17 taxa (28.81% of total taxa recorded in dry season), while Brachionidae was the most diverse family in the rainy season with 11 taxa (29.73% of

Table 1. List of rotifer fauna from Phu Ninh Lake, Quang Nam province (* = new to Vietnam, K = dry season, M = rainy season).

Collotheceae	<i>Lecane acanthinula</i> Hauer, 1938 ^{K*}
Collothecidae	<i>Lecane batillifer</i> Murray, 1913 ^K
<i>Collotheca ornata</i> (Ehrenberg 1832) ^{KM}	<i>Lecane bulla</i> Gosse 1851 ^{KM}
Flosculariaceae	<i>Lecane closterocerca</i> Schmarda 1859 ^{KM}
Conochilidae	<i>Lecane crepida</i> Haring 1914 ^K
<i>Conochilus dossuarius</i> (Hudson 1885) ^K	<i>Lecane curvicornis</i> Murray, 1913 ^{KM}
<i>Conochilus unicornis</i> (Rousselet 1892) ^{KM}	<i>Lecane doryssa</i> Haring, 1914 ^K
Trochosphaeridae	<i>Lecane thailandensis</i> Segers & Sanoamuang, 1994 ^{K*}
<i>Filinia camasecla</i> (Myers 1938) ^{KM}	<i>Lecane hamata</i> Stokes, 1896 ^{KM}
<i>Filinia longiseta</i> (Ehrenberg 1834) ^K	<i>Lecane hornemanni</i> Ehrenberg 1834 ^{KM}
Hexarthridae	<i>Lecane luna</i> Müller 1776 ^K
<i>Hexathra intermedia</i> (Wiszniewski) ^{KM}	<i>Lecane lunaris</i> Ehrenberg, 1832 ^{KM}
Testudinellidae	<i>Lecane obtusa</i> Murray, 1913 ^K
<i>Testudinella patina</i> (Hermann 1783) ^K	<i>Lecane rhenana</i> Hauer, 1929 ^K
Ploima	<i>Lecane pyriformis</i> (Daday, 1905) ^{K*}
Asplanchnidae	<i>Lecane ruttneri</i> Hauer, 1938 ^M
<i>Asplanchna priodonta</i> (Gosse 1850) ^{KM}	<i>Lecane sola</i> Hauer, 1936 ^{K*}
Brachionidae	<i>Lecane thienemani</i> Hauer, 1938 ^K
<i>Anuraeopsis navicula</i> (Rousselet 1911) ^{KM}	Lepadellidae
<i>Brachionus angularis</i> (Gosse, 1851) ^{KM}	<i>Colurella obtusa</i> Hauer, 1936 ^K
<i>Brachionus calyciflorus</i> (Pallas, 1766) ^{KM}	<i>Lepadella ovalis</i> Müller, 1786 ^K
<i>Brachionus caudatus</i> (Barrois & Daday 1894) ^{KM}	<i>Lepadella patella</i> Müller 1773 ^{KM}
<i>Brachionus dichotomus</i> (Shephard 1911) ^{KM}	Mytilinidae
<i>Brachionus diversicornis</i> (Daday 1883) ^K	<i>Mytilina ventralis</i> Ehrenberg, 1830 ^K
<i>Brachionus donneri</i> (Brehm, 1951) ^{KM}	<i>Mytilina bisulcata</i> Lucks, 1912 ^{K*}
<i>Brachionus falcatus</i> Zacharias, 1898 ^{KM}	Synchaetidae
<i>Brachionus forficula</i> Wierzejski 1891 ^{KM}	<i>Polyarthra dolichoptera</i> Idelson 1925 ^{KM}
<i>Brachionus patulus</i> Müller, 1786 ^K	<i>Polyarthra major</i> Burckhardt, 1900 ^{KM}
<i>Brachionus quadridentatus</i> Hermann 1783 ^{KM}	<i>Polyarthra vulgaris</i> Carlin 1943 ^{KM}
<i>Keratella cochlearis</i> Gosse 1851 ^{KM}	<i>Synchaeta stylata</i> Wierzejski 1893 ^{KM}
<i>Keratella quadrata</i> Müller 1786 ^K	Trichocercidae
<i>Keratella tropica</i> Apstein, 1907 ^{KM}	<i>Trichocera longiseta</i> Alexander, 1927 ^{KM}
Euchlanidae	<i>Trichocerca chattoni</i> de Beauchamp, 1907 ^{KM}
<i>Euchlanis dilatata</i> Ehrenberg 1832 ^{KM}	<i>Trichocerca cylindrica</i> Imhof 1891 ^{KM}
<i>Euchlanis meneta</i> Myers, 1930 ^K	<i>Trichocerca similis</i> Wierzejski, 1893 ^{KM}
Gastropodidae	Trichotriidae
<i>Ascomorpha ecaudis</i> Perty, 1850 ^{KM}	<i>Macrochaetus collinsii</i> Gosse 1867 ^K
<i>Ascomospha ovalis</i> Bergendal, 1892 ^{KM}	<i>Macrouchaetus longipes</i> Myers, 1934 ^K
<i>Ascomospha saltan</i> Bartsch, 1870 ^{KM}	<i>Trichotria tetractis</i> Ehrenberg, 1830 ^K
Lecanidae	

total taxa recorded in rainy season). The study also investigated that the average number of rotifer species per sample in the dry season (18 ± 8 taxa) was higher than that in the rainy season (11 ± 3 taxa) (Fig. 8).

To identify the species richness, we constructed species accumulation curves based on the rarefaction method, and fitted with a logarithmic model in each study site and in each season (Figs. 9, 10). The result

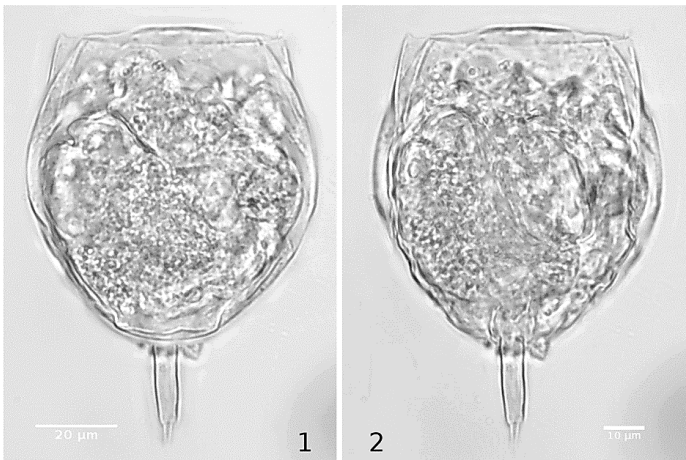


Figure 3. *Lecane acanthinula* Hauer, 1938, habitus - 1: dorsal view and 2: ventral view.

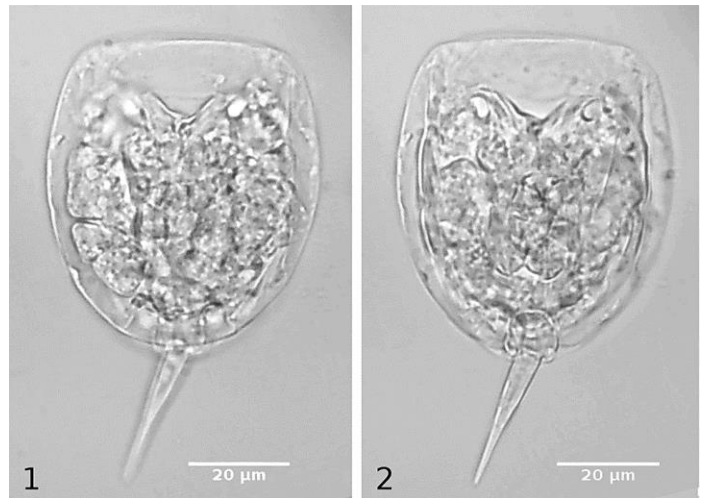


Figure 5. *Lecane pyriformis* (Daday, 1905), habitus - 1: dorsal view and 2: ventral view.

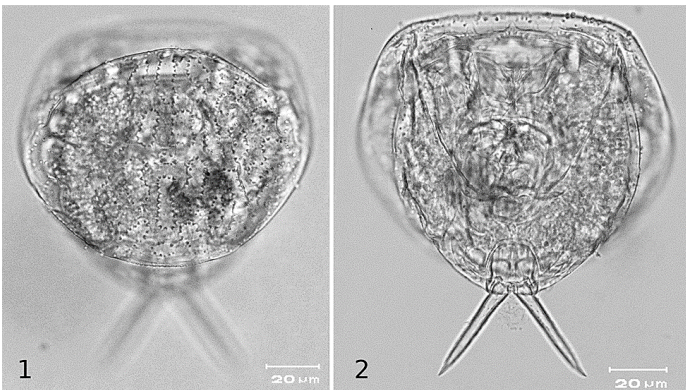


Figure 4. *Lecane thailandensis* Segers & Sanoamuang, 1994, habitus. 1: dorsal view and 2: ventral view.

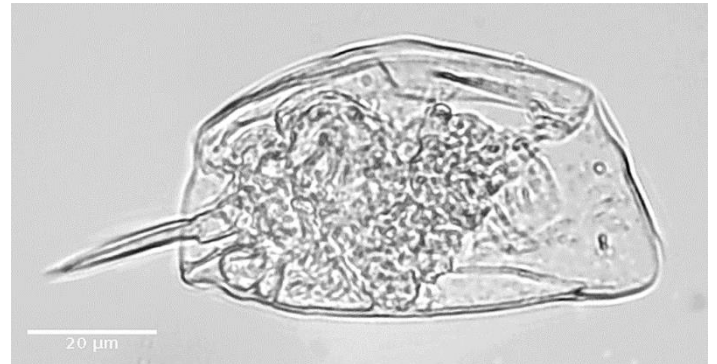


Figure 6. *Mytilina bisulcata* Lucks, 1912, habitus - lateral view.

showed that the average species number at each locality was 13 taxa, and the observed number of species in the pooled samples series was 61 taxa (Fig. 9). Besides, the number of species increased with the increase of sample size, following the equation $y=12.85+14.12\log(x)$ ($R^2=0.99$). Based on the estimators, the expected number of taxa in Phu Ninh Lake could be 71 ± 8 taxa (according to the Chao index), 79 taxa (according to Jackknife 2 index), and 67 ± 4 taxa (according to the Bootstrap index) (Fig. 9).

Comparing the species richness recorded between two seasons, the number of species in the dry season (59 taxa) was higher. Moreover, the number of recorded taxa also tended to increase with the increase of the sampling efforts in both seasons. The trend of increase was identified to follow the model as $y=16.93+15.3\log(x)$ ($R^2=0.998$) in the dry season and $y=10.11+10.02\log(x)$ ($R^2=0.998$) in the rainy season. This trend was also reflected in the cumulative curve

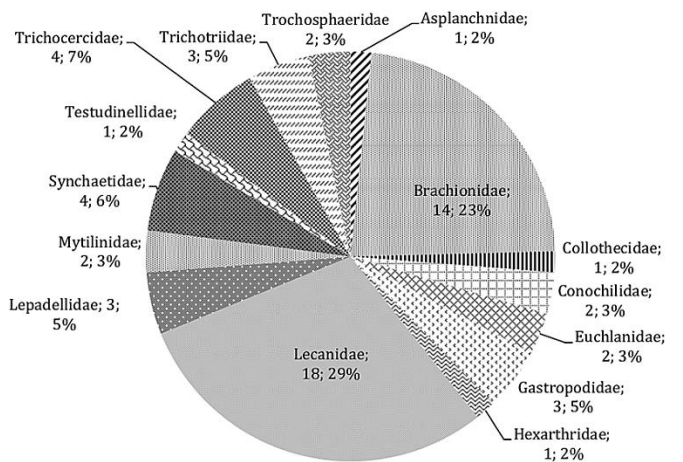


Figure 7. Percentage of species in each family of Rotifera in Phu Ninh Lake.

model, in which the model slope in dry season (15.30) was higher than that in rainy season (10.02). In addition, the estimator, which estimated the maximum number of taxa could be present in the lake, again confirmed the higher species diversity in the dry

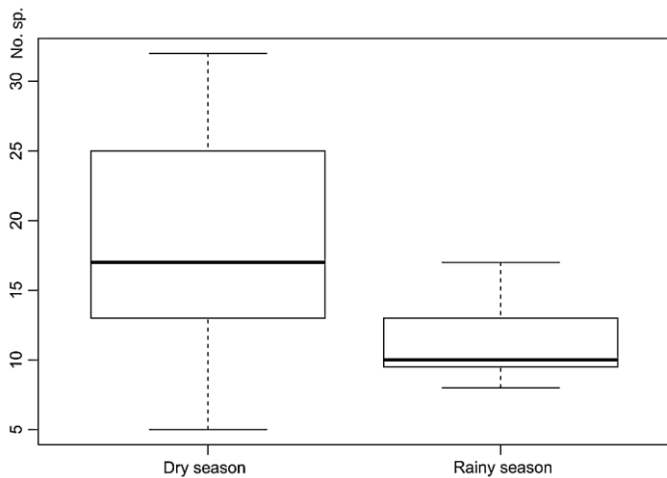


Figure 8. Boxplot showing the average species number of each sample between dry and rainy season at Phu Ninh Lake.

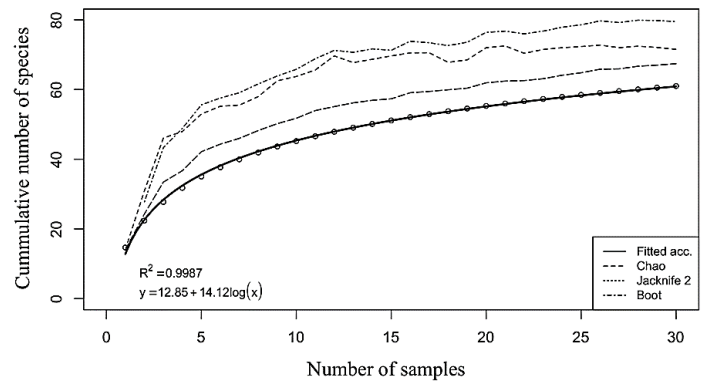


Figure 9. Species accumulator of species richness at study sites, with the fitted curve and estimator curve.

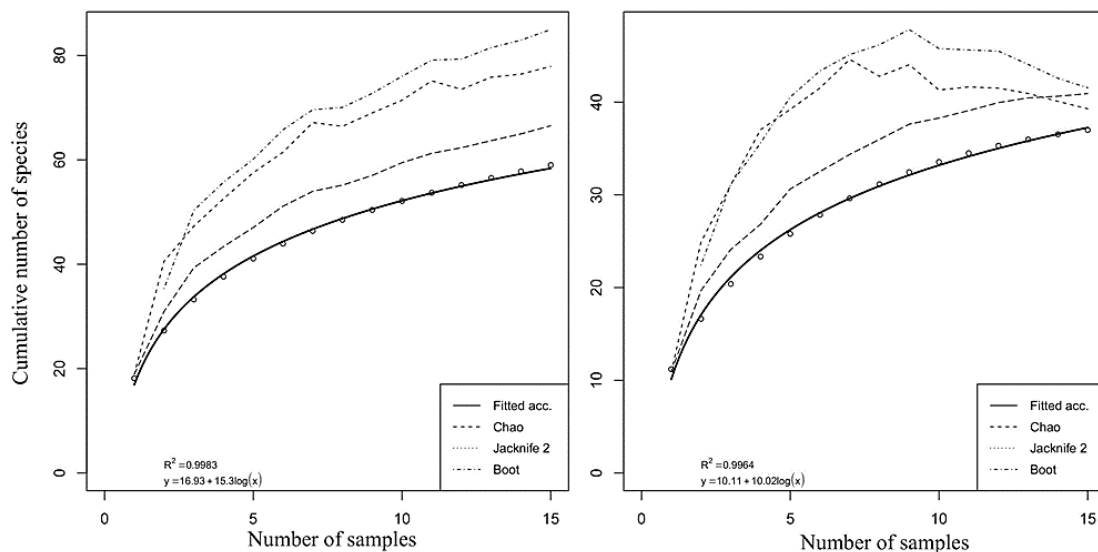


Figure 10. Species accumulator with fitted curve and estimator curve of species richness at study sites during dry (left) and rainy season (right).

season. In the detail, according to Chao 2 estimator index, the number of taxa that could appear in the dry season was 78 ± 13 taxa, and in rainy season was 39 ± 3 taxa. According to the Jackknife 2 index, these numbers were 85 taxa in the dry season, and 42 taxa in the rainy season. According to the Bootstraps index, the numbers were 67 ± 4 taxa and 41 ± 3 taxa in dry season and rainy season, respectively (Fig. 10).

Discussions

This study reports 61 taxa of rotifer for Phu Ninh Lake, Quang Nam Province, increasing the number of rotifer fauna for Vietnam to 227 taxa. Of 61 taxa identified from Phu Ninh Lake, *L. acanthinula* (Hauer,

1938), *L. sola* (Hauer, 1936), *L. thailandensis* Segers & Sanoamuang, 1994, *L. pyriformis* (Daday, 1905) and *M. bisulcata* (Lucks, 1912) are new to Vietnam. These results confirmed the high potential of rotifer diversity in the country.

The diversity of rotifer in Phu Ninh Lake was lower than that in some other freshwater bodies in the Central Vietnam such as Bau Thiem (89 taxa) and Thuy Tien lakes (82 taxa) in Thua Thien Hue Province (Trinh-Dang et al., 2013, 2015). It was also lower than the rotifer diversity of the Kud-thing Lake, Noing Kai Province, Northern Thailand (183 taxa). However, in compared to some lakes located in the Southern Vietnam (Tra Su=9 taxa, Bung Binh Thien=24 taxa,

Tri An=33 taxa (Dang and Nga, 2012), Da Ban=16 taxa, Kam Lam=19 taxa, Suoi Dau=20 taxa, and Suoi Trau=45 taxa (Zhdanova, 2011)) and a lake in Turkey (35 taxa) (Yağci and Ustaoglu, 2012), the Phu Ninh Lake showed a higher level of diversity.

Although there was a difference in the taxa number and rotifers species composition, the Phu Ninh Lake was rather similar to the two lakes in Thua Thien Hue Province (Thuy Tien and Bau Thiem lakes) (Trinh-Dang et al., 2013, 2015). In these three lakes, Lecanidae was the most abundant family (18 species with 27% and 42 species with 40%, respectively), followed by Brachionidae family (9 species with 13% and 11 species with 11%, respectively). This similarity might be due to the resemblance in the lakes environmental conditions. All these three lakes were the reservoirs with nutrients ranging from poor to medium (Trinh-Dang et al., 2013, 2015). This also explained the difference in the species structures between Phu Ninh Lake and other reservoirs such as Suoi Dau, Cam Lam and Da Ban reservoirs, where the Brachionidae was the most diverse family (Zhdanova, 2011).

Conclusions

With sixty-one taxa of rotifer and in which five new species for Vietnam recorded in Phu Ninh Lake, this study provided more evidence about the high potential of rotifers diversity in Vietnam. It is should be noted that rotifer species number in the lake does not stop at the number sixty-one since the study found that the taxa number tended to increase with the collected sample number. It is suggested that more surveys should be conducted in this site and also in other areas with different environmental conditions to supply more information on this group in Vietnam.

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