Land snail from limestone karst in Java: an update with notes on their distribution

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Abstract. Limestone karst in Java is rich of land snail fauna. Unfortunately, the ecosystem is now threatened by mining or tourism activities. However, the impact of that activities on land snail diversity is not well studied. The objective of this study was to inventory the diversity of land snail in limestone karst with focus on their ecological and distribution in Java. Purposive sampling methods using plots (10 x 10 m) were used in 12 different stations in Western Java, Central Java, and Yogyakarta during 2017-2018. Thirty-five species from eleven families of land snail were identified. The highest species richness and population of land snails were found in Watu Blencong (16 species and 158 individuals). \textit{Landouria rotatoria} distributed in eight locations, while \textit{Japonia ciliocinctum} (85 individuals) distributed in six locations. Results showed that extended distribution records of ten land snail species were reported. Currently, 63 species of land snails species have been identified in karst ecosystem in Java.

Keywords: Java, karst, land snail, distribution.

1. Introduction

Karst is unique landscape formed by slow erosion of limestone, which consist of calcium carbonate (CaCO\textsubscript{3}) [1]. Most karsts were formed millions of years ago by calcium-secreting marine organisms (e.g., corals and brachiopods) before tectonic movements lifted them above sea level [1]. The biodiversity in karst ecosystem is also unique, consisting of species that survive in highly alkaline environment, permanent dry conditions, and low oxygen, i.e. endemic species of land snail [2].

Land snails (Gastropoda) are the second most successful and diverse animal groups on land with an estimated 24,000 living species [3]. Most of land snails have a shell with various shape and color to protect from predator or unsuitable climate [4]. Limestone, a rich mineral soil, is abundant in karst area [1]. Some studies showed that land snail is dominant group (diversity and population) in karst ecosystem [5]. Compared to other natural ecosystem, land snail diversity and population in karst ecosystem was higher [4, 5].

In Java, karst ecosystem spread from west (Banten) to east (Banyuwangi), including its satellite island (Madura) [6]. Two important karst areas in Java are Gombong Selatan and Gunung Sewu. Karst is a source of ground water and also as tourism destination [6]. Human activities, such as mining, logging, road construction, and tourism are threatened of karts ecosystem [1, 2, 6].

Previous studies of fauna diversity in karst ecosystem in Java have been reported [7, 8, 9, 10]. In Menoreh karst area was reported 30 species of arthropods, 6 species of chiropterans [7], 9 species of...
fishes [8], 11 species of anurans [9], and 11 species of Odonata [10]. Meanwhile, in Gunung Sewu karst area was identified 6 classes, 30 orders, and 209 morphospecies of arthropods [11].

In ecosystem, land snails have important roles, such as food [12], crop pests [13, 14], host of parasites [15], decomposer [16, 17], and as bioindicator of environmental parameters [18, 19]. Study of diversity of land snails in karst ecosystems have been carried out during ten years ago [20, 21, 22, 23]. However, data of diversity and distribution of land snails in karst ecosystem in Java is still incomplete. The objective of this study was to inventory the diversity of land snails in limestone karst in Java related to their ecology and distribution.

2. Sampling stations and methods

2.1. Sampling sites

Sampling of land snails were carried out in 2017 and 2018. Twelve sampling plots (10 m x 10 m [24]) were set up in 12 stations (ST): 4 plots in Bogor-West Java, 3 plots in Purworejo-Central Java, and 5 plots in Gunung Kidul and Kulon Progo-Yogyakarta (figure 1). Land snails sampling sites were ST1 (Purwodadi village, District Tepus, Gunung Kidul regency, Province Yogyakarta (Gunung Bajo, Gunung Sewu karst area), ST2 (Kaligono village, District Kaligesing, Purworejo regency, Province Central Java (Menoreh karst area), ST3 (Leuwikare village, District Klapanunggal, Bogor regency, Province West Java (Klapanunggal karst area), ST4 (Leuwikare village, District Klapanunggal, Bogor regency, Province West Java, Klapanunggal karst areas), ST5 (Ciampea village, District Ciampea, Bogor regency, Province West Java (Ciampea karst areas), ST6 (Leuwengkolot village, District Cibunghulang, Bogor regency, Province West Java (Ciampea karst areas), ST7 (Jatimulyo village, District Girimulyo, Kulon Progo regency, Province Yogyakarta (Kembang Soka, Menoreh karst area), ST8 (Jatimulyo village, District Girimulyo, Kulon Progo regency, Province Yogyakarta (Grojogan Sewu, Menoreh karst area), ST9 (Jatimulyo village, District Girimulyo, Kulon Progo regency, Province Yogyakarta (Watu Blencong, Menoreh karst area), ST10 (Hargowilis village, District Kokap, Kulon Progo regency, Province Yogyakarta (Kali Biru, Menoreh karst area), ST11 (Donorejo village, District Kaligesing, Purworejo regency, Province Central Java (Goa Seplawan, Menoreh karst area), and ST12 (Donorejo village, District Kaligesing, Purworejo regency, Province Central Java (Gunung Kelir, Menoreh karst area).

All the stations were classified as natural ecosystem (NE: ST1), mining activities (MA: ST5), tourism activities (TA: ST7, 9, 10, 11), plantation area (PA: ST3, 6, 12), and near the settlements (NS: ST2, 4, 8).

![Figure 1](www.cavefauna.wordpress.com) Location of sampling sites of land snails (www.cavefauna.wordpress.com, with modification). A: ST 3-6, B: ST 2 and 7-12, C: ST1.

2.2. Sampling techniques

Land snails found in each plot were observed carefully for two hours. Both life and dead (shells) land snails were collected. Life specimens then were relaxed by drowning in water overnight and then
preserved in 70% ethanol. The shells was washed in running water, cleaned using a brush, and dried under the sun during the day. The locality of each stations were recorded. All specimens were brought to Museum Zoology Bogor and were identified based on references [25, 26, 27]. The species found was classified into Prosobranchia (mantle cavity widely open and possess an operculum to seal the aperture) and Pulmonata (mantle cavity with closable narrow pneumostome and no operculum). The land snail specimens then was classified based on their habitat and note of distributions.

2.3. Analysis
Characteristic species (species only was found in a one or group stations) was chosen to explain the uniqueness of each or a group stations [28]. Unique species, such as singleton (species represented by only one specimen) and doubleton (species represented by two specimens) were identified [29]. The relative abundance was determined based on the ratio of individuals found to the total number of individuals recorded. Frequency of distribution of species was calculated by the number of stations where the species found divided by the total number of sampled stations. Four groups species were classified based on their frequency: very accidental species (vac, frequency less than 10%), accidental species (acc, frequency varied 10-24%), common species (cmt, frequency varied 25–49%), and constant species (cst, frequency more than 50%) [30]. Biological rarity was determined by the number of specimens per species, while ecological rarity was determined by the number of station that species found [31, 32]. Land snails diversity was analysed by Shannon’s diversity index \( H' = \Sigma (ni/n) \ln (ni/n) \). Degree of equality of species in a certain environment was analysed by Pielou’s evenness index \( J=H'/\ln S \). Probability of two randomly sampled individuals belong to the same species was analysed using Simpson’s dominance index \( D = \Sigma (ni/n)^2 \). Note: S (number of species), ni (number of individual of species i), n (number of individual) [33]. Jaccard similarity was used to analyse similarity of species in between stations [29]. The cophenetic correlation coefficient (r) was used to measure the pairwise distances between the original data [34]. The categories are: very good fit (r > 0.9), good fit (0.8 < r < 0.9), poor fit (0.7 < r < 0.8), and very poor fit (r < 0.7) [35]. All statistical analysis were performed using PAST 2.17c [36].

3. Results

3.1. Land snails diversity
In total, 636 specimens of land snails were collected, consists of 11 families, 29 genera, and 35 species (Appendix). Pulmonata dominated the samples (404 specimens, 63.5%) belong to eight families, 17 genera, and 22 species. Prosobranchia was represented by 213 specimens (36.5%) belong to 2 families, 7 genera, and 13 species. Watu Blencong, Menoreh karst area (ST9) was the most diverse location (16 species, 158 specimens, 24.8%), while in Gunung Kelir, Menoreh karst area (ST12) was the least diverse (3 species, 6 specimens). Individual rarefaction of land snails in each station were showed in figure 2. “New finding species”, a species found in a station and never found in previous observations, was determined (figure 3). The dominant families of land snails was Cyclophoridae (204 specimens, 32%, 10 species) followed by Camaenidae (190 specimens, 29.8%, 8 species).

3.2. Species distribution
Japonia ciliocinctum (Prosobranchia: Cyclophoridae) was dominat species (85 specimens, 13.4%) followed by Elaphroconcha javacensis (Pulmonata: Ariophantidae (76 specimens, 12%). Meanwhile, Landouria rotatoria (Pulmonata: Camaenidae) was the most widely distributed species that found in eight stations. Number of specimen per species widely varied. We made a classification range based on the number of specimen. Within range of 1:10 specimens, 8 species, both Pulmonata and Prosobranchia were identified. Within ranges 11:20, 21:30, and 31:40 specimens, the number of species of Pulmonata was higher than Prosobranchia (figure 4). Results showed that four introduced species of Pulmonata (Parmarion pupillaris, Bradybaena similaris, Allopeas gracile, and Subulina octona) were identified.
Based on biological rarity, 6 species was found. Four singletons were identified, i.e., *Gyliotrachela fruhstorferi* (in ST1), *Prosopeas acutissimum* (in ST5), *Chamalycaeus longituba* (in ST9), and *Chloritis fruhstorferi* (in ST11). Meanwhile, 2 doubletons were identified (*Japonia convexum* (in ST1) and *Lamprocystis infans* (in ST3). In perspective of ecological rarity, more than half of the species had restricted range of station. Eighteen species were found in one station and 16 species in 2-6 stations. Eighteen species were classified as very accidental (vac, less than 10%, 1-17 specimens), 5 species were classified as accidental species (acc, 10-24%, 2-26 specimens), 7 species were classified as common species (cmt, 25-49%, 14-75 specimens), and 5 species was classified as constant species (cst, more than 50%, 19-85 specimens).

Species distribution of land snails varied based on condition of station. Pulmonata tend higher in all stations, except in NE (Prosobranchia was high) (figure 5). Characteristic species identified in NE were *Macrochlamys amboinensis*, *Cyclotus discoideus*, *Japonia convexum*, and *Gyliotrachela fruhstorferi*, in NS were *Amphidromus heerianus*, *Chamalycaeus longituba*, *Pupina compacta*, and *Pupina verbeeki*, in MA was *Lamprocystis infans*, in PA were *Chamalycaeus fruhstorferi*, *Chloritis fruhstorferi*, *Chloritis transversalis*, and *Paropeas acutissimum*. Two species, *Landouria rotatoria* and *Cyclophorus perdix* were found in all types of station condition.
They are mainly have small sized shell such as the last 7 species mentioned above. 

Present study results ten species as extended distribution records, i.e., 

3.5. Extended distribution records

Previously they reported from Java, but not from areas near to our observed locations. They are mainly have small sized shell such as the last 7 species mentioned above.
4. Discussion
Pulmonata is a group of land snail which breath using primitive lung, while Prosobranchia breath using advanced gills [13]. The ratio species of Pulmonata and Prosobranchia is 22:13. In average, results showed that the number of individual of Pulmonata (18.4 individuals) was higher than Prosobranchia (17.8 individuals). Previous study in Grobogan karst area were found the ratio of species Pulmonata and Prosobranchia was 10:23 and the ratio of individual was 1:11 [22]. The species distribution between Pulmonata and Prosobranchia was almost similar (2.68:2.38). This result is similar to previous studies in Sabah, Malaysian-Borneo which found that Pulmonata species tend more dominant and more evenly distributed than Prosobranchia [4, 5].

Based on the individual rarefaction (figure 1), increasing the individual number is not always followed by increasing the species number, such as in ST6 (55 individuals, 5 species), ST1 (81 individuals, 10 species), ST3 (94 individuals, 8 species). The highest was found in ST9 (158 individuals, 16 species). The number of individual in ST9 is almost twice in ST1. Meanwhile, new finding species (figure 2) also showed the same trends. The main peak were found in ST4 and ST5 (5 species), i.e., P. pupillaris, B. similaris, A. gracile, P. acutissimum, and S. octona. Both stations located in Bogor regency with distance between locations is about 28 km. The local condition may difference (ST4 is near the settlement and ST5 is near the limestone mining area). The second peak new species finding were observed in ST1-ST2, ST2-ST3, and ST8-ST9. It is interesting that after doing 9 sampling, we still found new finding (Chloritis fruhstorferi, Chloritis transversalis). It showed that the composition of land snail species in each station highly varied.

We summarized the results of this study together with previous studies of land snails in karst area in Java (table 1). Based on table 1, Pulmonata is dominant in all studies. Thirteen species (8 Pulmonata, 5 Prosobranchia) were similar with previous syudy in Sukolilo [22]. Four pulmonate species were similar with previous study in Gunung Sewu [20], while 9 Pulmonata genera and 4 Prosobranchia genera were similar with the later study in Gunung Sewu [21]. The later in Selo, Gunung Merbabu National Park, Boyolali regency, Central Java province is not karst area [23], but the location was close to this study. Previous study in Maros, Central Sulawesi [37] were identified 7 families, 17 genera, and 28 species and Pulmonata was dominated (5 families and 12 genera)
compared to Prosobranchia (1 family, 5 genera). The number of species of each group were similar (each 14 species).

A species that present with more than 50 individual was considered as the dominant species [38]. *J. ciliocinctum* (85 individuals, 13.4%) was found in 6 stations (44 individuals, 51% was found in ST9). They live in forest or bushes, a ground dweller in dead leaves, moss and other low vegetation. However, the domination species was never been mentioned by previous studies [20, 21, 22]. *Landouria rotatoria* was found in 8 stations. They live in forest or bushes, a ground dweller, decaying woods, under stones, and near human settlements. This species distributed in Sumatra, Java, Lesser Sunda Islands, and Phillipine Islands [26].

### Table 1. Comparison of land snails studied.

| Authors    | Prosobranchia | Pulmonata |
|------------|---------------|-----------|
|            | Family | Genera | Species | Family | Genera | Species |
| [20]       | 2      | 3      | 3       | 5      | 7      | 12      |
| [21]       | 3      | 9      | unidentified | 14   | 20     | unidentified |
| [22]       | 2      | 8      | 10      | 11     | 17     | 23      |
| [23]       | 2      | 3      | 8       | 9      | 20     | 37      |
| This study | 2      | 7      | 12      | 8      | 22     | 23      |

Results showed that land snails community have biological and ecological rarity. In the context of biological rarity, 4 singletons and 2 doubletons species have short range of endemism and prone to local and global extinction [29]. They need more attention in future by monitoring studies. Eleven Pulmonata and 7 Prosobranchia species occured only in one station, as very accidental species. In the ecological rarity context, the status of the species are threatened because they distributed in restricted range sizes. Meanwhile, 3 species of Pulmonata and 2 species of Prosobranchia occured in six stations, as constant species.

Based on the station conditions, more species were found in TA than other locations. TA consist of 4 stations, while the others only consist of 1-3 stations. The number of station maybe affected the number of species. Based on the field observation, modification of landscape were found in ST10, i.e., hiking track, office, mosque, garden, and play ground. This landscape may affected the local land snails community (6 species). In the other stations, landscape modification located in outside areas, such as parking area or restaurant (9-16 species). Ten species were observed in NE (ST1). Previous studies showed that the land snail diversity is commonly higher in the natural ecosystem compared to the other modified ecosystem [19, 29, 39].

The characteristic species of land snails found can be used as an indicator of their specialized habitat. Proportion of Pulmonata and Prosobranchia species within 5 station conditions varied, i.e., TA (5:0), MA (1:0), NS (1:3), PA (1:2), NE (2:2). Pulmonata was dominant in TA and MA, while Prosobranchia was not found in these two locations that highly affected by human activities. In NS and PA, Pulmonata was lower than Prosobranchia. In NE, undisturbed condition, both groups are equaly found. Pulmonata is more tolerant with the variation of habitat, while Prosobranchia is prefer in the undisturbed condition [19].

Based on the Shannon’s diversity index, ST9 showed highest diversity (16 species). Low Simpson’s dominance index showed no species dominant in all stations. Medium Pielou’s evenness index in ST3, ST4, and ST9 may be caused by the high individuals number of four species (*E. javacensis*, *L. rotatoria*, *C. perditis*, and *J. ciliocinctum*).

Grouping of station based on their species composition results three groups. First group (ST2, ST8, ST12) located in Menoreh karst area. Second group consist of two karst areas, i.e., Klapanunggal (ST3 and ST4) characterized by *J. grandipilum* and *L. infans* and Menoreh (ST7, ST9, ST10, ST11) characterized by eight characteristic species. *Helicarion albellus* was found in both karst areas. Third group (ST5, ST6) located in Ciampea karst area. Fourth group (ST1) located in Gunung Sewu karst.
area. However, they are more similar to the Klapanunggal karst area (represented by *L. winteriana* and *P. achatinaceum*) than Menoreh karst area (represented by *L. vitreum*).

Grouping species based on their distribution was affected by the condition of station. The first group was natural ecosystem (NE), second group as to tourism activities (TA), and third group as mining activities (MA). Ten records of species extended distribution found in this study was classified into two groups. First, species which previously recorded from western part of Java (*C. longituda*, *G. fruhstorferi*, *J. convexum*, *M. amboinensis*, *P. verbeeki*). Second, species which previously recorded from western and eastern part of Java (*C. fruhstorferi*, *C. transversalis*, *C. corniculum*, *C. discoideus*, *J. obliquistritum*) [25, 26, 27]. Now they are also found in central part of Java.

Previous studies on the land snails in karst ecosystem in Java have been reported. Fifteen species were reported from Gunung Sewu [20] and 33 species were reported from Sukolilo [22]. However, they found 6 similar species, so the total species known are 42 species. This study added 21 species of land snails, so the total species found in the karst ecosystem in Java was 63 species.

5. Conclusion

This study identified 35 species of land snails in karst areas in Java, consist of 22 species of Pulmonata and 13 species of Prosobranchia. *Landouria rotatoria* and *C. perdix* were found in all types condition observed. Grouping species based on their distribution was affected by the condition of station. However, grouping station based on their species composition was less affected by their location of karst areas. Pulmonata is more tolerant in varied habitat condition, while Prosobranch is prefers in the undisturbed condition. Currently, 63 species of land snails have been identified in karst ecosystem in Java.

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References

[1] Clements R, Sodhi N S, Schilthuizen M and Ng P K L 2006 *BioScience*. 56 733
[2] Murmamingtyas E, Darajati W and Sumardja E S (Eds) 2016 *Indonesian biodiversity strategy and action plan (IBSAP)* 2015-2020 (Jakarta: The National Development Planning Ministry/Agency for Assessment and Application of Technology)
[3] Lydeard C, Cowie R H, Ponder W F, Bogan A E, Bouchet P, Clark S A, Cummings K S, Frest T J, Gargominy O, Herbert D G, Hershler R, Perez K E, Roth B, Seddon M, Strong E E and Thompson F G 2004 *BioScience*. 54 321
[4] Schilthuizen M, Liew T S, Elahan B and Lackman-Ancrenaz I 2005 *Conserv. Biol*. 19 949
[5] Schilthuizen M, Chai H N and Kimsin T E 2003 *The Raffles. Bull. Zool*. 51 35
[6] Primajati M 2018 27 spesies fauna gua di kawasan karst maros-pangkep terancam masuk daftar merah. Available: https://www.liputan6.com/regional/read/3441060/27-spesies-fauna-gua-di-kawasan-karst-maros-pangkep-terancam-masuk-daftar-merah (In Indonesian Language)
[7] Harjanto S and Rahmadi C 2011 *Fauna. Indonesia*. 10 32 (In Indonesian Language)
[8] Hadiaty R K 2016 *J. Iktiol Indonesia*. 16 199 (In Indonesian Language)
[9] Qurniawan T F and Trijoko 2012 *J. Teknosains*. 2 55 (In Indonesian Language)
[10] Rachman H T and Rohman A 2016 *Int. J. Adv. Agric. Environ. Eng*. 3 255
[11] Kurniawan I D, Soesilohadi R C H, Rahmadi C, Caraka R and Pardamean B 2018 *Ecol. Environ. Conserv*. 24 72
[12] Schneider K, Meulen U, Marwoto R M and Djojosoebagio S 1998 *Tropicultura*. 17 59
[13] Barker G M (ed) 2002 *Molluscs as crop pests* (Wallingford (UK): CABI Publishing)
[14] Mujiono N 2010 *Berkala Ilmiah Biologi* 17 (*In Indonesian Language*)
[15] Djajasasmita M 1989 *Buletin Penelitian Kesehatan.* 17 135
[16] Mason C F 1970 *Oecologia.* 5 215
[17] Wolters V 1997 In Benckiser G (Ed). *Fauna in soil ecosystems: recycling process, nutrient fluxes, and agricultural production* (New York (USA): Marcel Dekker Inc) p 265
[18] Uys C, Hamer M and Slotow R 2010 *PlosONE.* 5 e9100
[19] Nurinsiyah A S, Fauzia H, Hennig C and Hausdorf B 2016. *Ecol. Indic.* 70 557
[20] Heryanto 2011. *Proc. Workshop Ecosystem Karst, Yogyakarta 18-19 October 2011* 167 (*In Indonesian Language*)
[21] Irsyad F L H, Sari F J P, Nurlela E, Cahyanto T and Nurinsiyah A S 2015 *Proc. Nat. Sem. Biol. Jakarta, 24 October 2015* 239 (*In Indonesian Language*)
[22] Nurinsiyah A S 2015 *Amer. Conchol.* 43 30
[23] Gamellia L N, Hidayat J W and Muhammad F 2017 *J. Biol.* 6 50 (*In Indonesian Language*)
[24] Nurinsiyah A S and Hausdorf B 2018. Diversity of land snail fauna of Java limestone area. *Mitt Dtsch Malakozool Ges.* 98 28
[25] Van Benthem Jutting W S S 1948 *Treubia.* 19 539
[26] Van Benthem Jutting W S S 1950 *Treubia.* 20 381
[27] Van Benthem Jutting W S S 1952 *Treubia.* 21 291
[28] Nori J, Gomez J M D and Leynaud G C 2011 *J. Nat. Hist.* 45 1005
[29] Oke C O and Chokor J U 2011 *Biosci Res J.* 23 63
[30] Chenchouni H, Menasria T, Neffar S, Chafaa S, Bradai L, Chaibi R, Mekahlia M N, Bendjoudi D and Abdelkrim Si Bachir A S 2015 *PeerJ.* 3:e860
[31] Bouchet P, Lozouet P, Maestrati P and Heros V 2002 *Biol. J. Linn. Soc.* 75 421
[32] Fontaine B, Gargominy O and Neubert E 2007 *Divers. Distrib.* 13 725
[33] Magguran A E 2004 *Measuring biological diversity* (Oxford (UK): Blackwell Publishing)
[34] Saracli S, Dogan N and Dogan I 2013 *J. Inequal Appl.* 2013 203
[35] Rohlf F J and Fisher J D L 1968. *Syst Zool.* 17 407
[36] Hammer Ø, Harper D A T and Ryan P D 2001 *Palaeontology Electronica.* 4 9
[37] Marwoto R M and Isnaningisih N R 2012 In Suhardjono Y R and Ubaidillah R (Eds). *Animal in Karst and Cave Maros South Sulawesi* (Jakarta (Indonesia): LIPI Press) p 115 (*In Indonesian Language*)
[38] Priawandiputra W, Nasution D J and Prawasti T S 2017. *IOP Conf. Series: Earth and Environ. Sci.* 58 1
[39] Ogbeide J O, Omogbeme M I, Uwaifo O P and Oke C O 2018 *Eur. Sci. J.* 14 366