Vol. 12(1): 191-202, January 2024
DOI: https://doi.org/10.23960/jsl.v12i1.819

Jurnal Sylva Lestari

P-ISSN: 2339-0913
E-ISSN: 2549-5747

Journal homepage: https://sylvalestari.fp.unila.ac.id

Full Length Research Article

Herpetofauna in Ranu Darungan and Blok Ireng-Ireng, Bromo Tengger Semeru National Park: Before-After the COVID-19 and Eruption

Berry Fakhry Hanifa[1,*], Quratul Aini[1], Muhammad Asmuni Hasyim[1], Luhur Septiadi[2]

[1] Biology Study Program, Faculty of Science and Technology, Universitas Islam Negeri Maulana Malik Ibrahim, Malang, Indonesia
[2] Wildlife Conservation Society – Indonesia Program, Bogor, Indonesia
[*] Corresponding Author. E-mail address: berryfhanifa@uin-malang.ac.id

ARTICLE HISTORY:
Received: 5 October 2023
Peer review completed: 12 December 2023
Received in revised form: 20 January 2024
Accepted: 2 February 2024

KEYWORDS:
Amphibian
Diversity
Herpetofauna
National Park
Reptile

ABSTRACT

The continuous eruption of the Bromo Tengger Semeru volcanic complex may have impacted the overall biodiversity in Bromo Tengger Semeru National Park, including amphibians and reptiles. On the other hand, restrictions on traveling during the COVID-19 pandemic may positively impact nature by minimizing the tourism-disturbance. This study analyzes the diversity of reptiles and amphibians before and after COVID-19 and Semeru eruption at Ranu Darungan and Blok Ireng-Ireng (utilization zone) of Bromo Tengger Semeru National Park during three continuous surveys (2019, 2021, and 2022). Preliminary sampling was conducted in August 2021, whereas extensive sampling was carried out in March–May 2022 using a visual encounter survey on two habitat conditions (terrestrial and aquatic); we used previous survey data for 2019. The continuous surveys in Ranu Darungan and Blok Ireng-Ireng showed the herpetofauna diversity consisting of 19 amphibian species (6 families) and 11 reptile species (5 families), where sampling effort in 2022 was adequate to reflect the overall herpetofauna diversity. There was a decrease in the species diversity index in Ranu Darungan after the Semeru eruption, indicating an increase in environmental stress for amphibians. However, the expected trend was not observed before and after the COVID-19 pandemic; other factors (besides reduced human activity at the site) may have contributed.

1. Introduction

The amphibian population has declined globally due to many factors, such as climate change, contamination, infectious diseases, and anthropogenic factors (Collins and Storfer 2003; Luedtke et al. 2023). Herpetofauna studies in watersheds in Greater Malang area of East Java as it serves an important role as an environmental bioindicator (Yanuarefa et al. 2012), have been carried out extensively based on the degree of herpetofauna diversity (Baihaqi et al. 2022; Devi et al. 2019, 2021; Elzain et al. 2018; Erfanda et al. 2019; Hanifa et al. 2022; Hidayah et al. 2018; Indawati et al. 2018; Septiadi et al. 2018). These studies also indicated that East Java has a high potential for herpetofauna diversity due to the abundance of reptiles and amphibians in several locations. Unfortunately, the number of areas that have high potential for herpetofauna diversity in East Java is not proportional to the interest of researchers to study and research herpetofauna to the utmost, so the number of studies related to amphibian reptile diversity is still relatively minimal in Malang, especially in Bromo Tengger Semeru National Park (BTSNP) and other regions in East Java. As was previously discussed, there has been a declining trend of reptiles and amphibians discovery rate (new species) in Indonesia in the last 70 years (Iskandar and Erdelen 2006). Amphibian population decline in Indonesia was due to numerous challenges, including low perception and knowledge, also low number and low quality of local herpetologists (Kusrini 2007).

National parks, i.e., BTSNP, are mandated to manage, conserve, protect, and preserve all flora, fauna, and ecosystems contained within the national park area as described in the Law of the Republic of Indonesia Number 5 of 1990 concerning Natural Resources and Ecosystem Conservation, so comprehensive information on species diversity in BTSNP is very crucial as a reference in management decision-making, e.g., establishment of sanctuary for threatened species, prioritizing the protection for the important conservation site, and recovery strategies for threatened species. As demonstrated in recent studies in BTSNP, e.g., on the new locality and easternmost distribution record of the Javan endemic Pearly Tree Frog, *Nyctixalus margaritifer* (Hanifa et al. 2023), and the rediscovery of the Bromo Tengger Semeru endemic snake, *Tetralepis fruhstorferi* (Septiadi et al. 2023). Along with these new discoveries, BTSNP has a high potential for herpetofauna diversity. BTSNP, administratively located in 4 districts, i.e., Malang, Pasuruan, Lumajang, and Probolinggo, still lacks reptile and amphibian diversity data information. This led us to explore and monitor the herpetofauna diversity in Ranu Darungan and Blok Ireng-Ireng of BTSNP.

In BTSNP, the herpetofauna survey was conducted in February 2019 (before the COVID-19 pandemic), where 11 species of herpetofauna (8 amphibian species and 3 reptile species) were recorded in Ranu Darungan and 7 species of herpetofauna (5 reptile species and 2 amphibian species) were reported in Blok Ireng-Ireng (Arroyyan et al. 2020). We continued this monitoring effort in August 2021 (the peak of the COVID-19 pandemic), when there were indications of an increase in the number of species; is this due to reduced human disturbance or perhaps a volcanic eruption? Therefore, monitoring herpetofauna diversity in previously surveyed areas is necessary, especially after the COVID-19 pandemic and the ongoing Semeru-Bromo volcanic eruption. In early December 2021, there was an eruption of Mount Semeru, which affected several surrounding areas. Mount Semeru experienced an increase in volcanic activity, which was marked by the occurrence of hot clouds that led to Pronojiwo and Candipuro Subdistricts, Lumajang Regency, East Java. This impacted several areas of BTSNP, especially Ranu Darungan and Blok Ireng-Ireng, which experienced ash rain with a thickness of up to 0.5 cm (Setiawan 2021).

Changes in the level of disturbance before and after the COVID-19 pandemic and differences in environmental conditions before and after the eruption of Mount Semeru (especially in 2019, 2021, and 2022) might be associated with the diversity and population dynamics of the vulnerable and sensitive amphibians and reptiles (Latifiana 2018). In this study, we investigated the herpetofauna diversity in Ranu Darungan and Blok Ireng-Ireng, BTSNP, by comparing the data of before-after COVID-19 pandemic and before-after Semeru eruption.

2. Materials and Methods

2.1. *Study Area and Data Collection*

Ranu Darungan is located on the southern slopes of Mount Semeru, which has dense and pristine highland rainforest vegetation. Some lakes and rivers flow quite swiftly in humid conditions. Ranu Darungan is also famous for its endemic orchid sanctuary. Meanwhile, Blok Ireng-Ireng is located on the eastern slope of the Mount Bromo Tengger Semeru complex, which is dominated by large tree vegetation and bamboo trees and humid conditions. Both study sites were characterized by the upper montane forest habitat, including the utilization zone frequently visited by visitors.

The surveys were conducted at night (7–11 pm) during March–May 2022 (three-fold, 1 survey for each month) in Ranu Darungan (112°55'35", -9°48'32") and Blok Ireng-Ireng (113°1'11", -9°57'15") of BTNSP, East Java, Indonesia (**Fig. 1**); the preliminary study was also conducted during August 2021 (one-fold) in Ranu Darungan; the 2019 observation in Ranu Darungan and Blok Ireng-Ireng (Arroyyan et al. 2020) will be used for this report.

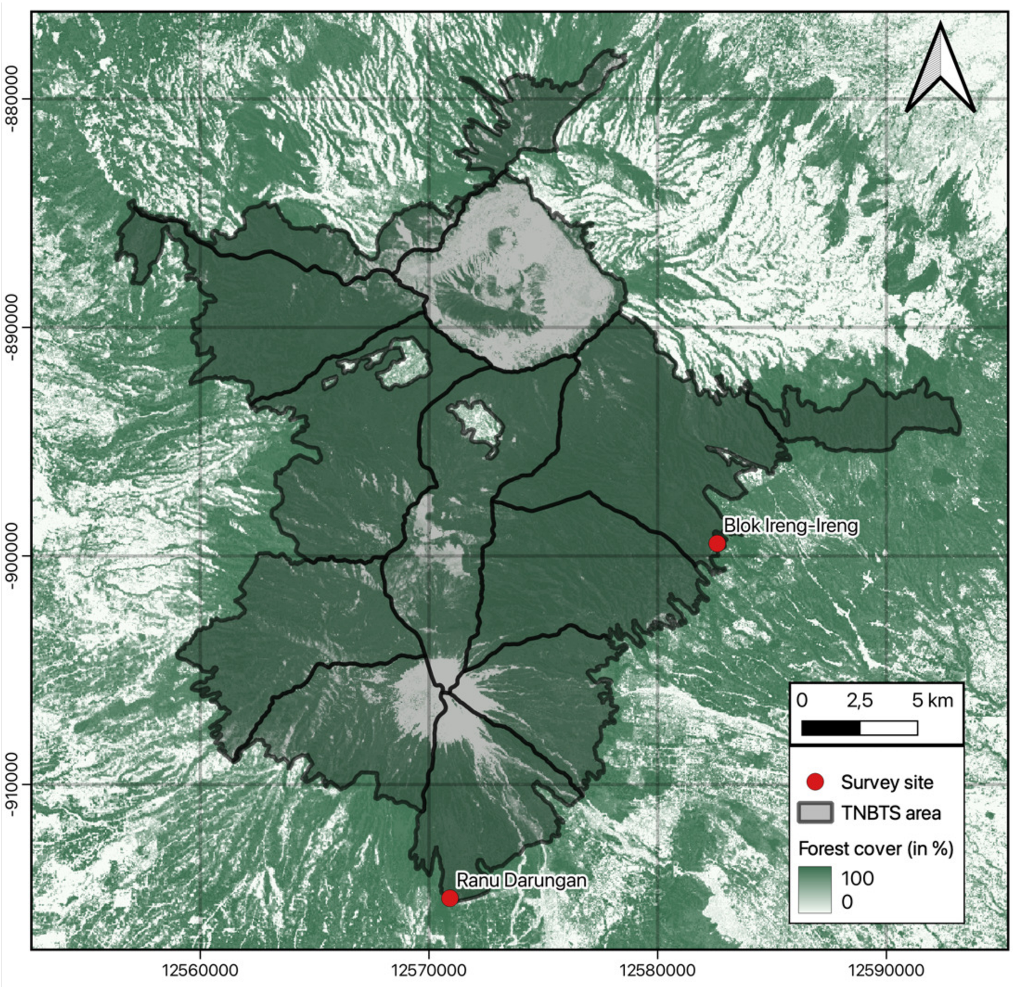

Fig. 1. Geographical map showing this study location in Bromo Tengger Semeru National Park.

This research is a descriptive quantitative study using the purposive sampling visual encounter survey (VES) method to facilitate and collect as many species and individuals of herpetofauna as possible and allow surveyors to explore as many areas of potential herpetofauna, which can be designed based on habitat conditions; we follow the previous protocol by Kurniawan et al. (2022). We actively searched for amphibians and reptiles and recorded environmental conditions using thermo-hygrometers to measure air temperature and humidity and water thermometers to measure water temperature. Surveyors were equipped with a flashlight, a small-medium sized bag as a temporary specimen container, a toolbox for sampling, a Canon DSLR camera as a documentation tool, a tally sheet, a Global Positioning System (GPS) to mark the coordinates of the samples, a timer, and an identification guidebook (Iskandar 1998; Kusrini 2013) to help with the identification process.

For Ranu Darungan (RD) and Blok Ireng-Ireng (BI), sampling plots were divided based on habitat type, i.e., aquatic and terrestrial areas (Yani et al. 2015), since both sites encompass these habitat types and to accommodate an adequate survey effort; however, this scheme was not implemented during the preliminary study on August 2021, and previous data (Arroyyan et al. 2020), but overall habitat. At RD, the aquatic area consisted of the area around the lake and spring, while the terrestrial area included the campground and forest around the lake. At BI, the terrestrial area included the Ireng-Ireng resort/office area, while the aquatic area included the river area. All collected individuals are released back into their habitat (after all data has been recorded), allowing them to reintegrate into their habitat. Finally, we get a dataset from 2019 (Arroyyan et al. 2020), 2021, and 2022 from RD and BI, covering before-after the COVID-19 pandemic and before-after the Semeru eruption (**Table 1**).

Table 1. Datasets used for the analysis in this study

Datasets	**Site**		**Habitat**		**Replicate**
	BI	**RD**	**Aquatic**	**Terrestrial**	
2019[a] (February 2019, before the COVID-19 pandemic)	✓	✓			One-fold
2021 (August 2021, after the COVID-19 pandemic, before the Semeru eruption)		✓			One-fold
2022 (March-May 2022, after the Semeru eruption)	✓	✓	✓	✓	Three-fold

Notes: BI: Blok Ireng-Ireng, RD: Ranu Darungan. The superscript indicates: [a] = data obtained from previous observations (Arroyyan et al. 2020).

2.2. Data Analysis

To investigate the sampling effort for each survey period in BI and RD, species diversity was compared against the sampling effort for each survey period using sample-size-based rarefaction and extrapolation sampling curves by iNEXT statistical software (Hsieh et al. 2016).

To determine the species diversity for each survey period in BI and RD, the data were estimated based on the Shannon-Wiener diversity index using Equation 1 (Nurudin et al. 2013; Odum 1993).

$$H' = -\sum\left[\left(\frac{ni}{N}\right) x \; ln \left(\frac{ni}{N}\right)\right] \tag{1}$$

where H' is defined as the Shannon-Wiener diversity index, ni is defined as the number of individuals in species-i, and N is defined as the total number of individuals encountered. We followed the classification proposed by Baliton et al. (2020), defining the H' ≥ 3.50 as very high, H' 3.00–3.49 as high, H' 2.50–2.99 as moderate, H' 2.00–2.49 as low, and H' ≤ 1.99 as very low. Furthermore, we compared diversity indices per survey period representing differences between RD and BI in 2022, differences between terrestrial and aquatic in 2022 in RD and BI, differences before and after the COVID-19 pandemic in Ranu Darungan (2019 vs. 2021), and differences before and after the Semeru eruption in Ranu Darungan (2021 vs. 2022), using Hutcheson *t*-test (Das et al. 2007; Hutcheson 1970).

3. Results and Discussion

3.1. Sampling Effort derives from Sample Size-based Rarefaction

Based on sample size-based rarefaction (**Fig. 2**), it shows the cumulative species richness (y-axis) that occurred during the survey period based on the number of individual amphibians and reptiles (x-axis) encountered (excluding recaptures). The accumulation curve begins to approach the asymptote for surveys in 2022 (RD and BI), indicating that sampling effort is effectively characterizing the community (but not observed in other surveys, e.g., preliminary surveys in RD during 2021 (this study) and previous study by Arroyyan et al. (2020) in BI and RD during 2019). These are likely to be associated with the inadequate sampling efforts that hindered the results on abundance or encountered amphibian and reptile species.

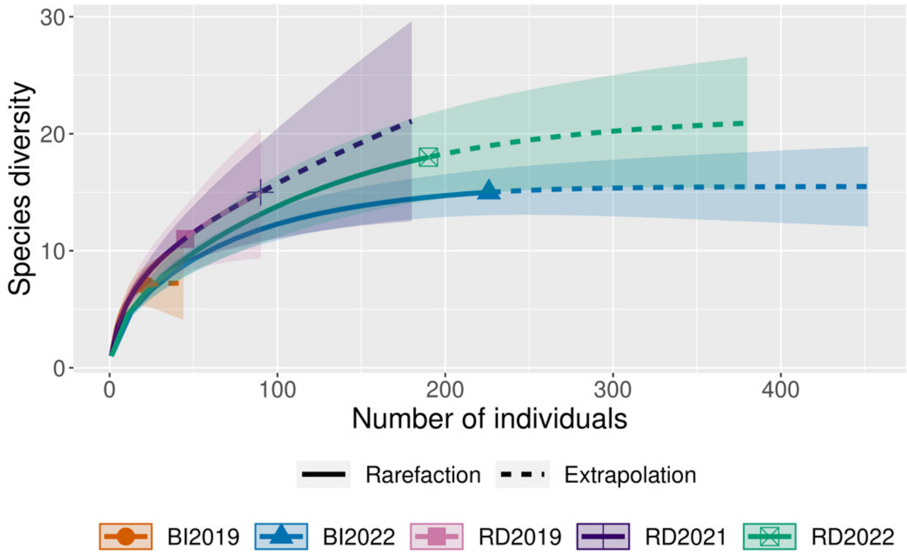

Fig. 2. Sample-size-based rarefaction (solid lines) and extrapolation (dashed lines) sampling curves representing each sampling effort in Blok Ireng-Ireng and Ranu Darungan during 2019, 2021, and 2022.

3.2. Amphibian and Reptile Composition and Diversity

The continuous surveys (2019, 2021, and 2022) in RD and BI showed the overall diversity of amphibians and reptiles consisting of 19 amphibian species (6 families) and 11 reptile species (5 families). In a recent study in RD during 2022, as many as 12 species of amphibians (5 families) and 6 species of reptiles (5 families) were recorded. In contrast, in 2022, as many as 10 species of amphibians (6 families) and 5 species of reptiles (4 families) were recorded in BI.

Based on preliminary surveys in RD during 2021, as many as 11 species of amphibians (4 families) and 4 species of reptiles (4 families) were recorded. Compared to the 2021 survey data, several species were not found in RD during the 2022 survey, i.e., *Limnonectes microdiscus*, *Occidozyga lima*, *Wijayarana masonii*, *Aplopeltura boa*, and *Dendrelaphis formosus*.

Based on previous surveys in RD and BI during 2019 (Arroyyan et al. 2020), RD had as many as 8 species of amphibians (5 families) and 3 species of reptiles (3 families). In contrast, BI had as many as 5 species of amphibians (2 families) and 2 species of reptiles (2 families). Compared to the 2019 survey data, several species were not found in RD during the 2022 survey, i.e., *Duttaphrynus melanostictus*, *W. masonii*, *Megophrys montana*, *Gekko gecko*, and *Eutropis multifasciata*; several species were not found in BI during 2022 survey, i.e., *Hylarana chalconota*, *Polypedates leucomystax*, and *Rhacophorus reinwardtii*. The overall abundance of encountered data on RD and BI during 2019, 2021, and 2022 is shown in **Table 2**.

Table 2. Species composition of reptiles and amphibians in BI and RD during 2019 (Arroyyan et al. 2020), 2021, and 2022

Taxon	**IUCN**	**2019[a]**		**2021[b]**	**2022[c]**			
		BI	**RD**	**RD**	**BI (Terrestrial)**	**BI (Aquatic)**	**RD (Terrestrial)**	**RD (Aquatic)**
Bufonidae								
Duttaphrynus melanostictus	LC	0	4	0	0	0	0	0
Leptophryne borbonica	LC	0	0	0	0	38	0	0
Dicroglossidae								
Fejervarya cancrivora	LC	0	0	0	0	1	0	0
Fejervarya limnocharis	LC	0	0	11	0	1	1	1
Limnonectes kuhlii	LC	0	0	0	0	4	1	1
Limnonectes microdiscus	LC	0	0	1	0	0	0	0
Occidozyga lima	LC	0	0	7	0	0	0	0
Ranidae								
Wijayarana masonii	LC	5	7	2	0	4	0	0
Hylarana chalconota	LC	2	6	26	0	0	19	77
Hylarana nicobariensis	LC	0	0	1	0	0	0	16
Odorrana hosii	LC	3	16	25	0	27	0	2
Rhacophoridae								
Nyctixalus sp.	LC	0	0	0	2	0	1	0
Philautus aurifasciatus	LC	0	0	0	113	8	3	0
Polypedates leucomystax	LC	4	1	1	0	0	1	2
Rhacophorus reinwardtii	LC	5	3	4	0	0	5	0
Megophrydae								
Leptobrachium haseltii	LC	0	0	0	0	0	0	2
Megophrys montana	LC	0	1	0	2	0	0	0
Microhylidae								
Microhyla achatina	LC	0	4	3	5	0	7	5
Microhyla palmipes	LC	0	0	5	0	0	26	13
Agamidae								
Bronchocela cristatella	LC	0	0	0	2	0	0	0
Bronchocela jubata	LC	2	0	1	5	0	1	1
Gonocephalus kuhlii	VU	0	0	0	7	0	0	0
Gekkonidae								
Cyrtodactylus marmoratus	LC	0	0	1	5	0	1	0
Gekko gecko	LC	0	1	0	0	0	0	0
Scincidae								
Eutropis multifasciata	LC	0	1	0	0	0	1	0
Colubridae								
Ahaetulla prasina	LC	0	1	0	0	0	0	1
Dendrelaphis formosus	LC	0	0	1	0	0	0	0
Rhabdophis chrysargos	LC	0	0	0	0	0	0	1
Pareidae								
Aplopeltura boa	LC	0	0	1	0	0	0	0
Pareas carinatus	LC	1	0	0	2	0	0	1
∑ Individual		22	45	90	143	83	67	123

Notes: BI: Blok Ireng-Ireng, RD: Ranu Darungan, LC: Least Concern, VU: Vulnerable, Σ: Total, Superscript indicates: [a] = 2019, before COVID-19 pandemic, [b] = 2021, after COVID-19 pandemic, before Semeru eruption, and [c] = 2022, after Semeru eruption.

3.3. Environmental Conditions During Surveys

This difference in species richness could be due to differences in humidity and temperature, in which amphibians and reptiles might have their preferences, as previously observed in other regions in the world (Laurencio and Fitzgerald 2010; Qian et al. 2007). Temperatures in the RD and BI were relatively stable between 20–25°C with high humidity ranging from 78–87%. However, RD had lower temperatures and higher humidity than BI during the survey period, which may explain the higher species richness. The presence of Ranu Linggo Rekisi Lake in RD likely provides a suitable habitat for amphibians and reptiles. Environmental conditions (temperature and humidity) in RD and BI during 2019, 2021, and 2022 are shown in **Table 3.**

Table 3. Average temperature and humidity recorded in RD and BI during 2019 (Arroyyan et al. 2020), 2021, and 2022 surveys

Parameter	**2019[a]**		**2021[b]**		**2022[c]**	
	RD	**BI**	**RD**	**BI**	**RD**	**BI**
Temperature (°C)	23.3	21	23	-	21.7	23.1
Humidity (%)	78	80	78	-	87	78

Notes: BI: Blok Ireng-Ireng, RD: Ranu Darungan. The superscript indicates: [a] = 2019, before the COVID-19 pandemic, [b] = 2021, after the COVID-19 pandemic, before the Semeru eruption, and [c] = 2022, after the Semeru eruption.

Temperature has a major influence on the community structure and sustainability of herpetofauna communities. For example, most amphibians with mucous glands (which are used to regulate temperature and moisturize the body) can experience great stress at higher temperatures or lower humidity because they can lose large amounts of water from their skin surface (Churchill and Storey 1993; Toledo and Jared 1993). This also explains why amphibians have a tendency to remain nocturnal as a form of behavioral adaptation to anticipate these environmental conditions (Iskandar 1998). While no significant direct human disturbance to herpetofauna populations was observed in RD and BI during the surveys, other indirect disturbances are still possible, such as the presence of litter. In line with previous studies, amphibians can respond negatively to tropical forest conditions disturbed by human activities (Hanifa et al. 2022) because amphibians are sensitive and vulnerable animals (Mistar 2003).

3.4. Comparing the Herpetofauna Before-After the COVID-19 Pandemic and the Semeru Eruption

Significant differences existed between the survey periods in BI and RD during 2019, 2021, and 2022. The most recent survey (2022) showed no site-related differences (BI vs. RD) during 2022, with similar diversity index values (H' = 1.61–1.68; very low diversity). Although H' showed very low diversity, there were habitat-related differences (terrestrial vs. aquatic) in RD and BI during 2022, showing a higher diversity index value in terrestrial for RD (H' = 1.73; very low diversity) and a higher diversity index in aquatic for BI (H' = 1.35; very low diversity). When comparing the diversity before-after the COVID-19 pandemic, there were no period-related differences (2019 vs. 2021) in RD, only similar diversity index values before-after the COVID-19 pandemic (H' = 1.96–2.02; very low to low diversity). In the before-after Semeru eruption, there was a period-related difference (2021 vs. 2022) in RD, which showed a higher diversity index before the Semeru eruption (H' = 2.02; low diversity). Although sampling efforts may have varied, there were observable differences between sites, habitats, and periods. The overall comparison of diversity indices on RD and BI during 2019, 2021, and 2022 is shown in **Table 4.**

There was a decrease in the species diversity index in RD after the Semeru eruption (which was also observed in species diversity and composition), indicating an increase in environmental stress for amphibians and reptiles. However, the expected trend was not observed before and after the COVID-19 pandemic, which had a similar diversity index, indicating that other factors (besides reduced human activity at the site) may have contributed.

Table 4. Statistical summary of Hutcheson *t*-tests, comparing species diversity in Ranu Darungan (RD) and Blok Ireng-ireng (BI) before-after the COVID-19 and the Semeru eruption

Site	H_x	H_y	$t_{cal.}$	$t_{crit.}$	Statistical value
Recent period (2022)					
Ranu Darungan vs Blok Ireng-Ireng	1.68	1.61	1.60	1.97	df = 399, $p \geq 0.05$
Based on habitat in RD (2022)*					
Terrestrial vs Aquatic	1.73	1.36	2.06	1.97	df = 161, $p \leq 0.05$
Based on habitat in BI (2022)*					
Terrestrial vs Aquatic	0.92	1.35	2.81	1.97	df = 222, $p \leq 0.05$
Before-after COVID-19 in RD					
2019 vs 2021	1.96	2.02	0.32	1.98	df = 101, $p \geq 0.05$
Before-after eruption in RD*					
2021 vs 2022	2.02	1.68	2.23	1.97	df = 218, $p \leq 0.05$

Notes: BI: Blok Ireng-Ireng, RD: Ranu Darungan. The asterisk indicates significant differences ($p \leq 0.05$).

The pandemic hit Indonesia since early 2019 when the government officially imposed work rules and restrictions on leaving the house in mid-March 2019. The regulations continue to develop given the potential dangers of the COVID-19 pandemic, e.g., with the issuance of Government Regulation Number 21 of 2019, Government Regulation Number 19 of 2021, Government Regulation Number 60 of 2021, Government Regulation Number 1 of 2022, Government Regulation Number 42 of 2022, and Government Regulation Number 47 of 2022. Restrictions on these activities are likely to positively impact natural tourism areas by drastically reducing visitor levels, thereby reducing human disturbance to existing ecological communities. The regulation temporarily suspended tourism activities in BTSNP in March 2020 (Wulung et al. 2021). It is noteworthy that tourist visits in BTSNP increased dramatically from year to year, which can be summarized as follows: approximately 424,391 tourist visits in 2016 (Achmad 2021), approximately 623,895 tourist visits in 2017 (Achmad 2021), approximately 669,422 tourist visits in 2019 (Hemawati 2020), and approximately 825,206 tourist visits in 2018 (Ramadhan 2021); visitor trends may not be accurate due to differences in methods used and the opening and closing of national parks due to the new normal scheme. However, visitors in 2020 were the lowest in the last 5 years since 2016 (Achmad 2021). This may allow time for nature to recover, as also could be seen in the species diversity in general. To the best of our knowledge, no specific data is available on visitors to the RD and BI. However, RD and BI are areas that are vulnerable to human activities. RD is often used for research activities; some visitors do birdwatching and see orchid sanctuaries, and there is easy access from the nearest villages. BI is an area dominated by pristine forests and rivers but very close to road access, where some trash can be found around the area.

Changes in habitat conditions around BI and RD will likely affect the survival of existing fauna. Setiawan (2021) stated that the impacts of volcanic eruptions vary and are adjusted to the distance and direction of the volcanic eruption. Both research locations fall into the category of mild-moderate volcanic ash impact. However, these habitat changes can potentially disrupt the survival of animals in the wild, especially reptiles and amphibians that are relatively vulnerable to environmental changes. Mount Semeru's eruption in early December 2021 has impacted the ecosystem around the BTSNP area. Several areas were severely affected, including the BTSNP area. RD was one of the areas most severely impacted by the eruption, while BI was slightly affected. As the ecosystem changes due to acid rain caused by the eruption, amphibians are one of the most affected vertebrates in the ecosystem. Post-eruption data can also be influenced by the increased disturbance after the COVID-19 pandemic due to the new normal regulations issued in stages that allow some tourist sites to be widely opened to the public up to a certain level.

4. Conclusions

The diversity of herpetofauna in RD and BI during the 2019, 2021, and 2022 surveys can be considered low. However, there was a decrease in the species diversity in RD after the Semeru eruption, indicating the relapse process of the herpetofauna community. The expected trend was not observed before and after the COVID-19 pandemic, showing a similar degree of herpetofauna diversity, where other factors (besides reduced human activity at the site) may have contributed. The presence of reptiles and amphibians can be affected by habitat changes, both natural and artificial, which also indicates the response of reptile and amphibian communities to habitat changes. Continuous surveys are needed to monitor the trend of diversity and population of amphibians and reptiles in BTSNP.

Acknowledgments

The authors thank Bromo Tengger Semeru National Park (BTSNP) for giving us permission to conduct this research (SI.08/T.8/BIDTEK/BIDTEK.1/DIK/3/2022), as well as to BTSNP officers who help us in preparing field study and provide lodging. This study was supported by "Maliki Herpetology Society" and "Ecology Team" of Biology Department, Universitas Islam Negeri Maulana Malik Ibrahim Malang, especially C. R. Achmad, M. N. Riskananda, M. N. Izzulhaq, B. Syamsiyah, M. M. Fatansyah, D. R. Azizi, M. A. Hasanuddin, M. W. Nauval, K. Rimakhusshofa, S. Hana, M. R. Ridho, M. A. Fadhilah, N. A. Azizah, A. A. Mustofa, I. Nurdhiana, A. M. S. P. Soeprijadi, Dzulqarnain, Fikron, A. P. Baihaqi, F. A. Afifuddin, F. Hidayat, and A. Maghfironi. We thank IDEAWILD for providing the equipment used in the study. This study was financially supported by Litapdimas of Kementerian Agama Republik Indonesia Research Grant (Registration No: 221140000059527 to Berry F. Hanifa; Registration No: 221140000059528 to Muhammad. A. Hasyim) and the Rufford Small Grant for Nature Conservation (Project ID: 36547-1 to Luhur Septiadi).

References

Achmad, T. 2021. Selama Pandemi Covid-19 Tahun 2020, 196.391 Wisatawan Kunjungi TNBTS. Malang Times. <https://www.malangtimes.com/baca/68117/20210605/174900/selama-pandemi-covid-19-tahun-2020-196-391-wisatawan-kunjungi-tnbts>

Arroyyan, A. N., Idrus, M. R., and Aliffudin, M. F. 2020. Keanekaragaman Herpetofauna di Kawasan Taman Nasional Bromo Tengger Semeru (TNBTS) Kabupaten Lumajang Jawa Timur. *Prosiding Seminar Nasional Biologi di Era Pandemi COVID-19* 263–269. DOI: 10.24252/psb.v6i1.15862

Baihaqi, A. P., Ahmad, M., Kiptiyah, Hasyim, M. A., and Hanifa, B. F. 2022. Herpetofauna in the Ledok Ombo Natural Tourism Area, Malang District, East Java. *Al-Hayat* 5(2): 127–138. DOI: 10.21580/ah.v5i2.13566

Baliton, R. S., Landhicho, L. D., Cabahug, R. E. D., Paelmo, R. F., Laruan, K. A., Rodriguez, R. S., Visco, R. G., and Castillo, A. K. A. 2020. Ecological Services of Agroforestry Systems in Selected Upland Farming Communities in the Philippines. *Biodiversitas Journal of Biological Diversity* 21(2): 707–717. DOI: 10.13057/biodiv/d210237

Churchill, T. A., and Storey, K. B. 1993. Dehydration Tolerance in Wood Frogs: A New Perspective on Development of Amphibian Freeze Tolerance. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology* 265(6): 324–332. DOI: 10.1152/ajpregu.1993.265.6.r1324

Collins, J. P., and Storfer, A. 2003. Global Amphibian Declines: Sorting the Hypotheses. *Diversity and Distributions* 9(2): 89–98. DOI: 10.1046/j.1472-4642.2003.00012.x

Das, I., Jankowski, A., Makmor, M. I. B., and Haas, A. 2007. Species Diversity, Elevational Distribution and Reproductive Modes in an Amphibian Community at the Matang Range, Sarawak (Borneo). *Mitteilungen aus dem Hamburgischen Zoologischen Museum und Institut* 104(1): C34.

Devi, S. R., Elang, A., Herlambang, N., Hanifa, B. F., and Muchtaromah, B. 2021. Analisis Hubungan Kekerabatan Genus *Cyrtodactylus* Berdasarkan Gen ND2 Secara in Sillico di Jawa Timur. *Prosiding Seminar Nasional Sains dan Teknologi Terapan* 4(1): 345–353.

Devi, S. R., Septiadi, L., Erfanda, M. P., Hanifa, B. F., Firizki, D. T., and Nadhori, Q. 2019. Struktur Komunitas Ordo Anura di Lokasi Wisata Bedengan Desa Selorejo Kecamatan Dau Kabupaten Malang. *Jurnal Riset Biologi dan Aplikasinya* 1(2): 71–79. DOI: 10.26740/jrba.v1n2.p71-79

Elzain, L. Z. L., Alwi, M. Z., Mahali, M. A., Maghrobi, Septiadi, L., and Hanifa, B. F. 2018. Studi Awal Potensi Keanekaragaman Reptil Amfibi di Lokasi Wisata Alam Coban Pelangi Poncokusumo, Malang, Jawa Timur. *Seminar Nasional Biologi - Universitas Negeri Semarang* 136–144.

Erfanda, M. P., Septiadi, L., Devi, S. R., and Hanifa, B. F. 2019. Distribution Record of *Leptophryne borbonica* (Tschudi, 1838) (Anura: Bufonidae) from Malang, East Java: Description, Microhabitat, and Possible Threats. *Journal of Tropical Biodiversity and Biotechnology* 4(2): 82–89. DOI: 10.22146/jtbb.45355

Hanifa, B. F., Hasyim, M. A., Prahardika, B. A., and Agustin, N. W. 2022. Reptiles and Amphibian Diversity, Along with Potential Treat in Sumber Nyolo, Malang Regency. *El-Hayah* 8(4): 130–135. DOI: 10.18860/elha.v8i4.15799

Hanifa, B. F., Septiadi, L., Hasyim, M. A., Fathoni, M., Prabasari, K., Erfanda, M. P., Rahmadana, M., Widjanarko, H., and Kurniawan, N. 2023. New Data on and the Easternmost Record of the Javan Endemic Pearly Tree Frog, *Nyctixalus margaritifer* Boulenger, 1882 (Anura, Rhacophoridae). *Check List* 19(6): 971–982. DOI: 10.15560/19.6.971

Hemawati, R. 2020. Sepanjang 2019 Pengunjung Bromo Tembus 690 Ribu Orang. Media Indonesia. <https://mediaindonesia.com/nusantara/287032/sepanjang-2019-pengunjung-bromo-tembus-690-ribu-orang>

Hidayah, A., Hanifa, B. F., Devi, S. R., Septiadi, L., Alwi, M. Z., and Afifudin, F. A. 2018. Keanekaragaman Herpetofauna di Kawasan Wisata Alam Coban Putri Desa Tlekung Kecamatan Junrejo Kota Batu Jawa Timur. *Prosiding Seminar Nasional Hayati* 6(1): 79–91. DOI: 10.29407/hayati.v6i1.660

Hsieh, T. C., Ma, K. H., and Chao, A. 2016. iNEXT: an R Package for Rarefaction and Extrapolation of Species Diversity (Hill Numbers). *Methods in Ecology and Evolution* 7(12): 1451–1456. DOI: 10.1111/2041-210x.12613

Hutcheson, K. 1970. A Test for Comparing Diversities Based on Shannon Formula. *Journal of Theoretical Biology* 29: 151–154. DOI: 10.1016/0022-5193(70)90124-4

Indawati, Y., Hanifa, B. F., Septiadi, L., Alwi, M. Z., Khatimah, A., and Azizah, I. 2018. Keanekaragaman Jenis Herpetofauna Nokturnal di Area Coban Jahe, Desa Pandansari Lor, Kecamatan Tumpang, Kabupaten Malang, Jawa Timur. *Prosiding Seminar Nasional Hayati* 6(1): 277–285. DOI: 10.29407/hayati.v6i1.635

Iskandar, D. T. 1998. *Amfibi Jawa dan Bali*. Puslitbang Biologi LIPI, Bogor.

Iskandar, D. T., and Erdelen, W. R. 2006. Conservation of Amphibians and Reptiles in Indonesia: Issues and Problems. *Amphibian and Reptile Conservation* 4(1): 60–87. DOI: 10.1514/journal.arc.0040016

Kusrini, M. D. 2007. Konservasi Amfibi di Indonesia: Masalah Global dan Tantangan. *Media Konservasi* 7(2): 89–95. DOI: 10.29244/medkon.12.2.%25p

Kurniawan, N., Septiadi, L., Fathoni, M., Kadafi, A. M., and Marhendra, A. P. W. 2022. A Checklist of the Herpetofauna of Nusa Kambangan Island, Central Java, Indonesia. *Tropical Life Sciences Research* 33(2): 91–131. DOI: 10.21315/tlsr2022.33.2.6

Kusrini, M. D. 2013. *Panduan Bergambar Identifikasi Amfibi Jawa Barat*. Fakultas Kehutanan IPB, Bogor.

Latifiana, K. 2018. Pemetaan Habitat Potensial Herpetofauna pada Daerah Terdampak Erupsi Gunung Merapi 2010. *Seminar Nasional Geomatika* 3: 497–510.

Laurencio, D., and Fitzgerald, L. A. 2010. Environmental Correlates of Herpetofaunal Diversity in Costa Rica. *Journal of Tropical Ecology* 26(5): 521–531. DOI: 10.1017/s0266467410000222

Luedtke, J. A., Chanson, J., Neam, K., Hobin, L., Maciel, A. O., Catenazzi, A., Borzée, A., Hamidy, A., Aowphol, A., Jean, A., and Sosa-Bartuano, Á. 2023. Ongoing Declines for the World's Amphibians in the Face of Emerging Threats. *Nature* 622(7982): 308–314. DOI: 10.1038/s41586-023-06578-4

Mistar. 2003. *Panduan Lapangan Amfibi: Kawasan Ekosistem Leuser*. The Gibbon Foundation and PILI NGO Movement. Bogor, Indonesia.

Nurudin, F. A., Kariada, N., and Irsadi, A. 2013. Keanekaragaman Jenis Ikan di Sungai Sekonyer Taman Nasional Tanjung Puting Kalimantan Tengah. *Unnes Journal of Life Science* 2(2): 118–125.

Odum, E. P. 1993. *Dasar-Dasar Ekologi*. Gadjah Mada University Press, Yogyakarta.

Qian, H., Wang, X., Wang, S., and Li, Y. 2007. Environmental Determinants of Amphibian and Reptile Species Richness in China. *Ecography* 30(4): 471–482. DOI: 10.1111/j.0906-7590.2007.05025.x

Ramadhan, L. A. 2021. Sepanjang Tahun 2020 Angka Kunjungan Wisatawan ke Gunung Bromo Terjun Bebas. Berita Jatim. <https://beritajatim.com/gaya-hidup/angka-kunjungan-wisatawan-ke-gunung-bromo-terjun-bebas/>

Septiadi, L., Hanifa, B. F., Khatimah, A., Indawati, Y., Alwi, M. Z., and Erfanda, M. P. 2018. Studi Keanekaragaman Reptil dan Amfibi di Lokasi Wisata Ledok Amprong Poncokusumo, Malang, Jawa Timur. *Jurnal Biotropika* 6(2): 45–53. DOI: 10.21776/ub.biotropika.2018.006.02.02

Septiadi, L., Idrus, M. R., Arroyyan, A. N., Fathoni, M., Erfanda, M. P., Devi, S. R., Hanifa, B. F., Priambodo, B., Sidik, I., and Kurniawan, N. 2023. Found But Forgotten: On the Records, Misidentification, and Potential Rediscovery of the Rare Bromo Tengger Semeru Mountain Endemic Snake (Serpentes: Colubridae: *Tetralepis fruhstorferi*). *Russian Journal of Herpetology* 30(4): 249–254. DOI: 10.30906/1026-2296-2023-30-4-249-254

Setiawan, R. 2021. Gunung Semeru Erupsi, Warga di Kecamatan Pronojiwo Kena Dampak. Tirto.id. <https://tirto.id/gunung-semeru-erupsi-warga-di-kecamatan-pronojiwo-kena-dampak-gly1>

Toledo, R. C., and Jared, C. 1993. Cutaneous Adaptations to Water Balance in Amphibians. *Comparative Biochemistry and Physiology Part A: Physiology* 105(4): 593–608. DOI: 10.1016/0300-9629(93)90259-7

Wulung, S. R. P., Latifah, A. N., Saidah, A. F., Ningtias, A. S., and Yasyfa, F. 2021. Dampak Covid-19 pada Destinasi Pariwisata Prioritas Bromo Tengger Semeru. *Jurnal Ilmiah Pariwisata* 26(2): 123–132. DOI: 10.30647/jip.v26i2

Yani, A., Said, S., and Anto, E. 2015. Keanekaragaman Jenis Amfibi Ordo Anura di Kawasan Hutan Lindung Gunung Semahung Kecamatan Sengah Temila Kabupaten Landak Kalimantan Barat. *Jurnal Hutan Lestari* 3(1): 15–20. DOI: 10.26418/jhl.v3i1.8877

Yanuarefa, M. F., Hariyanto, G., and Utami, J. 2012. *Panduan Lapang Herpetofauna (Amfibi dan Reptil) Taman Nasional Alas Purwo*. Balai Taman Nasional Alas Purwo, Banyuwangi.