

# Structure of soil Collembola communities as bioindicators in conservation areas of West Lombok, West Nusa Tenggara, Indonesia

IMMY SUCI ROHYANI\*, AHMAD JUPRI, ISROWATI

Environmental Science Study Program, Faculty of Mathematics and Natural Sciences, Universitas Mataram. Jl. Majapahit 62, Selaparang, Mataram 83125, West Nusa Tenggara, Indonesia. Tel./fax.: +62-370-646506, ✉email: immysuci@yahoo.co.id

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**Abstract.** Rohyani IS, Jupri A, Isrowati. 2025. Structure of soil Collembola communities as bioindicators in conservation areas of West Lombok, West Nusa Tenggara, Indonesia. *Biodiversitas* 26: 4374-4383. Conservation areas maintain the diversity of plants, animals, types of ecosystems, and natural uniqueness, as well as the protection of soil, water, climate, and historical and cultural values within them. One effort to maintain the function of conservation areas is improving soil fertility by maximizing the role of soil organisms, one of which is soil Collembola. This research aims to analyze the community structure of Collembola and utilize its potential as a bioindicator of soil conditions in four conservation areas in West Lombok District, West Nusa Tenggara Province, Indonesia. The research locations include Kerandangan Nature Tourism Park, Suranadi Nature Tourism Park, and Nuraksa Forest Park in the Protection Block and Utilization Block. The approach used is quantitative descriptive-exploratory. Samples were taken purposively using pitfall traps, chicken bait traps, and soil sampling, then extracted with a Berlese funnel. Community structure was analyzed using diversity indices, species richness, dominance, and evenness. The potential of bioindicators was assessed based on the relationship between the abundance of the Collembola genus and soil environmental parameters (organic C, total nitrogen, moisture, water content, available phosphorus and Cation Exchange Capacity/CEC). The results showed a stable community structure, with high genus richness and evenness, moderate diversity, and low dominance. The genera *Isotomiella*, *Pseudosinella*, and *Callyntrura* have the potential to be used as bioindicators of low organic carbon, total nitrogen, soil moisture, and water content. The genera *Mimoderus*, *Proisotoma*, *Pseudachorutes*, *Oudemansia*, and *Pseudoparonella* have the potential to be used as bioindicators of low phosphorus availability and soil cation exchange capacity. This finding suggests the potential of Collembola as an effective bioindicator for monitoring soil quality in sustainable conservation area management.

**Keywords:** Collembola genus, edaphic conditions, indicator organisms, soil biodiversity, West Lombok

## INTRODUCTION

Conservation areas in Lombok Island in Indonesia important to study due to their unique geographical and zoogeographical location, being situated in the Wallace Line region, the transition zone between Asian and Australian flora and fauna (Ngakan et al. 2023). West Lombok District, in West Nusa Tenggara Province, has a number of conservation areas that are important for maintaining ecological functions while also supporting the socio-economic resilience of the local community (Yumantoko et al. 2024). Conservation areas in this region not only serve to preserve natural resources and biodiversity but also support ecotourism activities, environmental education, and local ecological resilience. Some of the main conservation areas that are centers for conservation and nature tourism destinations are Kerandangan Nature Park, Suranadi Nature Park, and Nuraksa Forest Park, each with different ecosystem characteristics, anthropogenic pressures, and management functions.

Kerandangan Nature Tourism Park and Suranadi Nature Tourism Park, protect various species of the endemic flora and fauna of Lombok, contributes directly to ecosystem conservation and serves as an ecotourism destination that supports the local economy. Ecotourism based on nature

conservation provides opportunities for local communities to earn income from tourism activities without negatively impact the nature. Nuraksa Forest Park plays an essential role in maintaining soil fertility, preventing erosion, and maintaining the quality of water resources that are vital to the lives of local communities (Nuraksa Grand Forest Park Office 2019). Conservation areas, in general, are essential in maintaining and improving soil quality through various ecological mechanisms. Good soil quality (fertile) supports the success and sustainability of conservation areas (Zhang et al. 2025). Fertile soil provides good ecosystem support and is essential in maintaining the balance of nature in conservation areas (Lu et al. 2025).

Maintaining soil fertility can be done by optimizing the biotic and abiotic components. Biotic components include soil organisms, which contribute to maintaining soil fertility (Harto et al. 2021). Soil organisms, including Collembola, play an essential role in the decomposition process and energy flow; therefore, they can affect soil fertility. Collembola are one of the most abundant groups of soil fauna in forest soils (Orgiazzi et al. 2016), and they are important in maintaining soil health (Yang et al. 2025). According to Joimel et al. (2022), Collembola can show optimal environmental quality. Soil Collembola are important in maintaining the stability of forest soil ecosystems (Budiaman et al. 2023). They maintain soil

fertility by functioning as decomposers and bioindicators (Harto et al. 2021). Collembola are bioindicators of soil condition because they are susceptible to habitat changes in structure and community function (Trianto and Marisa 2020).

Collembola, as representatives of mesofauna, are closely related to the soil environment (Potapov et al. 2020). Based on the morphological adaptations of Collembola for survival in various soil layers, they are classified into euedaphic species (living in true soil), hemiedaphic (living in litter), and epedaphic (living on the surface of litter) (Potapov et al. 2016). Collembola are highly sensitive to environmental changes, such as variations in soil moisture, resource supply, and habitat structure (Fujii et al. 2020; Zhang et al. 2023). The presence of soil Collembola in a habitat is influenced by abiotic components: temperature, pH, humidity, soil moisture content, toxic substances or pollutants, and season or climate (Kuznetsova et al. 2018). Soil Collembola have an important ecological role in food chain processes, energy flows, and material cycles (Xu et al. 2019). Collembola play an active role in the breakdown of organic matter (Niwangtika and Ibrohim 2017). Collembola regulate the activity of bacteria and fungi, including mycorrhizal fungi that live in symbiosis with plant roots (Pollierer and Scheu 2021; Gruss et al. 2022). When feeding on fungal hyphae, parts of the organism are not digested and are extracted with feces, causing their spread to other soil layers. Collembola also contribute to the spread of bacteria in the soil, including nitrogen-fixing bacteria (Kuřáková et al. 2018). Collembola also affect the structure and porosity of the soil and can increase the

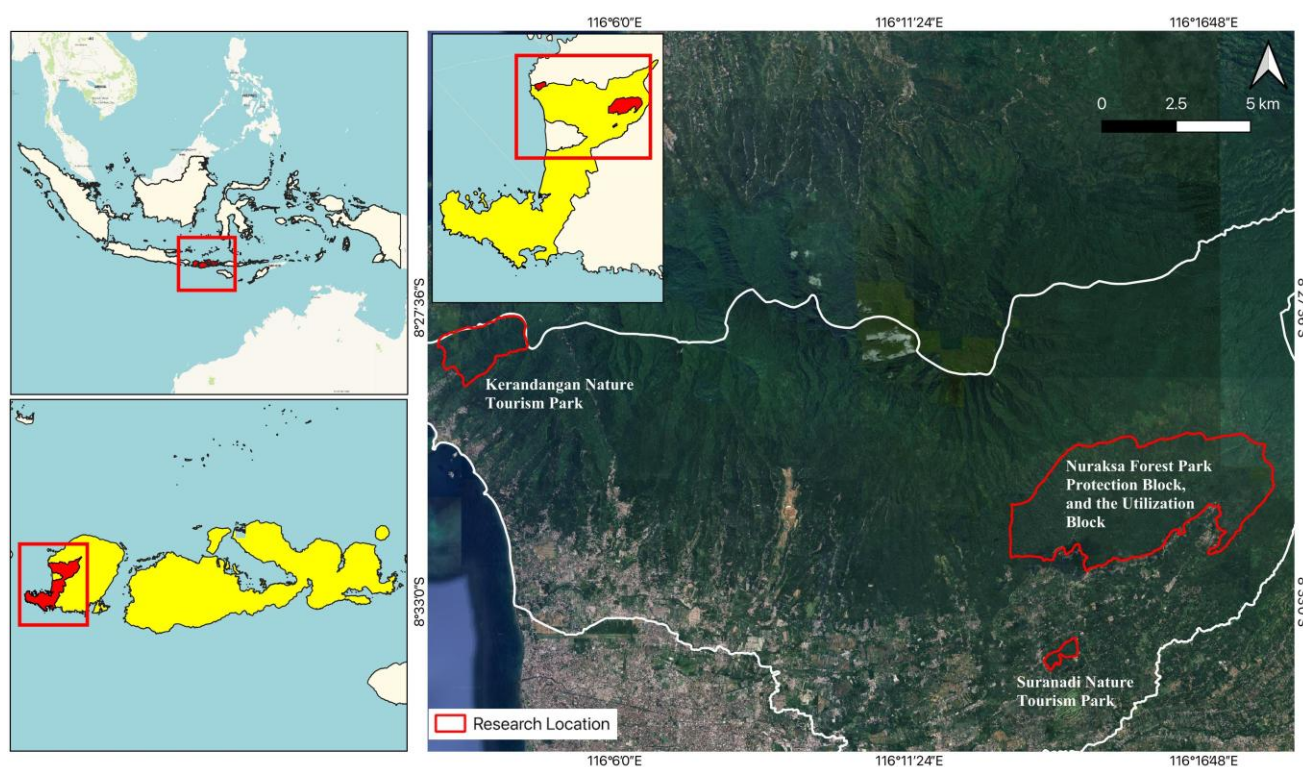
content of nutrients and humus in the soil (Gruss et al. 2022).

The presence of soil Collembola plays a crucial role in enhancing soil fertility and should be optimized as an innovative approach to the sustainable development and management of conservation areas. As permanent residents of the soil ecosystem, Collembola serve as reliable indicators of soil fertility, offering a more effective and efficient method for monitoring changes in conservation areas compared to traditional physical and chemical analyses. Research on the diversity of soil Collembola in conservation areas in West Lombok is important to conduct in an effort to optimize the role of soil Collembola, which can support the success of conservation efforts thru the maintenance of nutrient cycles, soil fertility, and biological balance. This study aims to analyze the structure of soil Collembola community in several conservation areas and estimate their potential as a bioindicator for monitoring soil fertility. The findings of this research will be of interest to those interested in sustainable management of conservation areas.

## MATERIALS AND METHODS

### Research location and time

A quantitative research design is used with a descriptive-exploratory approach. The research locations (Figure 1) in West Lombok, West Nusa Tenggara, Indonesia, included Kerandangan Nature Tourism Park, Suranadi Nature Tourism Park, and Nuraksa Forest Park Protection Block, and the Utilization Block.



**Figure 1.** Map of conservation area research locations in West Lombok, West Nusa Tenggara, Indonesia

### Sampling method

The study used the purposive sampling method to select the sample. Soil Collembola sampling used a 100 meter long main transect line at each research site. On the main transect line, every 10 meters, a distance of 5 meter was made, and an additional perpendicular (horizontal) transect line was made to the right and left. Three soil Collembola traps were randomly installed at each point made on the main and additional transects. The traps used to collect Collembola were pitfall traps, traps with chicken bait and a soil sampling method by taking soil samples at the research location and storing them in cloth bags to then be extracted with heat using a Berlese funnel and preserved with 70% ethanol. Soil Collembola active on the soil surface were collected using pitfall traps made of plastic cups with a base diameter of 5.5 cm and 10 cm. Next, the prepared traps were immersed in the dug holes, then given a roof (using smooth zinc) as high as ±30 cm from the ground surface, to prevent water from entering when it rains. The traps were filled with 70% ethanol and 3 drops of glycerin for preservation. Ten traps were installed at each research location, with three days of trap installation in the field and seven days of extraction in a barrel funnel (Rohyani and Ahyadi 2017).

The identification of soil Collembola was carried out up to the morphospecies level by looking at the characteristics of the soil Collembola caught, which were matched with identification keys using Pictorial Keys to Soil Animal of China (Yin 2000), Collembola (Suhardjono et al. 2012), and Checklist of the Collembola of the World (Janssens 2023). Identification was carried out at the genus level at the Faculty of Mathematics and Natural Sciences Laboratory of Universitas Mataram, West Nusa Tenggara, Indonesia.

Analysis of soil physical and chemical properties involved direct field observation and laboratory analysis. The physical properties of the soil measured directly in the field were soil temperature using a soil thermometer, and soil moisture and pH using a soil pH-moisture meter. For chemical analysis, 500 grams of soil were taken from each plot using a soil drill using the composite method. The soil samples were taken from each plot point and then thoroughly mixed at each research location. Each soil analysis sample was repeated three times. Soil texture was determined through laboratory analysis using the pipette method. The chemical properties of the soil measured were water content by drying the soil at a temperature of 110°C for 24 hours, Organic C using the Walkley and Black method, analysis of total soil Nitrogen (N) content using the wet destruction method (Kjeldahl), Available Phosphorus (P) was analyzed using the Bray-1 method and measured using a spectrophotometer to determine the phosphorus content, and determination of Cation Exchange Capacity (CEC) using the Leaching method (washing) with 1 N Ammonium Acetate pH 7.

### Data analysis

The data analysis included the analysis of Relative Abundance (RA) (Magurran 2012). Relative Abundance (RA) is the abundance of a genus divided by the sum of the

abundance of all genera in a community, multiplied by 100%. Type richness is calculated using the Margalef richness index (Dmg) (Magurran 2012). The diversity of soil Collembolas was determined according to the Shannon-Wiener diversity index (H') (Magurran 2012). Species equality is used to determine the value of equality between species in a community calculated using the Evenness index (E) (Magurran 2012). The dominance (D) of a type centered in the community is measured using the Simpson dominance index (Magurran 2012).

$$\text{Relative abundance (\%)} = \frac{\text{Absolute abundance of a species}}{\text{Total absolute abundance of a species}} \times 100\%$$

$$\text{Margalef index } Dmg = \frac{S - 1}{\ln(N)}$$

$$\text{Shannon index } H' = - \sum_{i=1}^s p_i \ln(p_i)$$

$$\text{Evenness index } E = \frac{H'}{\ln(S)}$$

Where, S: The total number of species in a sample/community; n: The number of individuals of the i-th species, where i: 1, 2, ..., S; N: The total number of individuals in a sample/community; N:  $\sum$ ; p<sub>i</sub>: The proportion of the i-th species (frequency or relative abundance, n<sub>i</sub>/N)

## RESULTS AND DISCUSSION

### Environmental conditions of conservation areas in West Lombok as a habitat for soil Collembola

The measurement of environmental conditions in Kerandangan Nature Tourism Park showed different results from those in Suranadi Nature Tourism Park, Nuraksa Forest Park Utilization Block, and Nuraksa Forest Park Protection Block (Table 1). The most noticeable differences in the results of the measurement of the micro-environmental conditions in Kerandangan Nature Tourism Park were observed in soil temperature, air temperature, CEC, and the highest percentage of sand. In contrast, soil moisture, air humidity, soil moisture content, soil pH, % Organic C, and % Nitrogen was the lowest compared to other locations. The high temperature observed in Kerandangan Nature Tourism Park might cause low humidity due to increased evaporation, which can cause a decrease in soil moisture content. The soil moisture content was found to be low in Kerandangan Nature Tourism Park.

High soil temperature can accelerate the decomposition of organic matter by soil microorganisms (Pompeo et al. 2016). This condition can lead to the low percentage of Organic C in the soil and the high value of soil CEC. Rapid decomposition of organic matter results in the high value of CEC (Rohyani 2021). According to Purnamasari et al. (2024), organic C accumulation occurs because the soil decomposes more slowly due to lower temperatures. Climatic conditions, including soil temperature and humidity, also affect the rate of decomposition of organic matter and the formation of Organic C (Maulana et al. 2024). Silaen (2020) noted that moisture, acidity, and soil

temperature affect the decomposition process of organic matter. Rainfall and land use can also affect soil Organic C levels (Rahmi et al. 2024). High soil temperatures can also accelerate the process of mineralization and volatilization, lowering the total N percentage of soil. The low percentage of total soil N is also influenced by the low level of organic C in the soil. The low percentage of total soil N is also influenced by the low level of organic C in the soil. According to Kuśmierz et al. (2023) the organic C content of the soil influences the availability of total N in the soil.

The analysis of the soil texture in Kerandangan Nature Tourism Park (Table 1) showed that the textural class of the soils was clayey sandy soils. This textural class is different from those in other locations in the sandy clay textural class. Soil texture is a physical property of soil that also affects the structure of soil communities. The physical properties of this soil are directly linked to the original condition or shape of the soil. The soil texture indicates the size and relative proportions of different soil particles. The proportion of sand, clay, and dust present in the soil determines this texture. The clay-sand soil texture with a high percentage of sand in Kerandangan Nature Tourism Park is thought to influence low humidity, air content, pH, organic C and total N in the area. According to Zega (2024), soil texture affects porosity and the ability to absorb and release groundwater. Soil texture affects the number of pore spaces in the soil, including soil moisture content (Rohyani 2021). The texture of the soil affects the amount of Organic C content in the soil. Sandy soils have a lower Organic C content (Kuśmierz et al. 2023). According to Yim et al. (2022) sandy soil texture can reduce the diversity of soil organisms and affect microbial mobility.

The condition of the microhabitat in Kerandangan Nature Tourism Park might be an important factor in the low abundance of Collembola in the location (Table 1). According to Silaen (2020), changes in environmental conditions will affect the abundance and diversity of Collembola in the soil. As noted by Suhardjono et al. (2012), elevated soil temperatures can affect the growth, reproduction, and metabolism of soil Collembola. The slightest temperature fluctuation in the soil significantly

affects the presence of Collembola in an area (Suin 2018). Collembola tolerance to high temperatures and drought differs between species (Escribano-Álvarez et al. 2022). The high and low soil moisture content also affects the abundance of soil Collembola (Husamah et al. 2016). Soil moisture, soil temperature, and soil pH support the survival of Collembola in soils (Geovani et al. 2023). Soil moisture has an important role in determining the distribution pattern of Collembola (Suhardjono et al. 2012). The maximum humidity required by Collembola to survive is 100%, while the minimum humidity is 50%. (Geovani et al. 2023). Humidity is the most important factor that determines the structure of the Collembola community which is sensitive to low humidity (Zhang et al. 2023). According to Rohyani (2012), soil moisture plays a role in the presence of soil Collembola, making it an indicator of groundwater conditions.

The pH value of the soil in Suranadi Nature Tourism Park was 6.8, which tends to be neutral, the highest Organic C, total Nitrogen, and Available Phosphorus compared to other research sites. A neutral soil pH supports the diversity of soil microorganisms, including bacteria and fungi, which are the food source for many soil Collembola. A near-neutral soil pH (6.5-7.5) supports the availability of nutrients such as calcium, magnesium, and molybdenum, as well as soil microbial activity that is important for soil fertility (Meena and Ritambhara 2022). According to Widrializa (2016) soil pH is one of the limiting factors affecting Collembola's life and activities. pH and water content were identified as the most important abiotic factors associated with the Collembola community (Susanti et al. 2024).

Organic C content in Suranadi Nature Tourism Park was high, indicating that many organic materials are available. This finding is in accordance with that of Rohyani (2021). High Organic C content indicates a high level of organic matter in the soil, which can increase the activity of decomposers, thus creating a richer food chain. The presence of Organic C will spur the activity of soil microorganisms, increasing the soil respiration rate (Wibowo and Lestari 2019).

**Table 1.** Results of micro-habitat measurements in several West Lombok, West Nusa Tenggara, Indonesia, conservation areas

Environmental conditions	Kerandangan Nature Tourism Park	Suranadi Nature Tourism Park	Nuraksa Forest Park Utilization Block	Nuraksa Forest Park Protection Block
Soil temperature (°C)	29-30	24-26	26-28	26-27
Soil moisture (%)	55	75	76	72
Air temperature (°C)	28-29	27-28	26-27	26-28
Air humidity (%)	66	78	70	80
Soil pH	5.4	6.8	5.6	5.8
Soil water content (%)	3.76	6.2	6.94	6.46
Organic C (%)	2.19	6.13	4.18	4.24
Total nitrogen (%)	0.09	0.21	0.2	0.15
Available P (ppm)	29.05	59.51	8.7	10.32
CEC (meq%)	4.22	3.83	0.62	1.36
Sand (%)	81.87	71.2	64.6	63.2
Silt (%)	15.53	22.82	29.48	31.86
Clay (%)	2.6	5.98	5.72	4.94
Texture class	Clay-Sand	Sandy Clay	Sandy Clay	Sandy Clay

A high concentration of organic matter in the soil affects the total N level, according to Khalif et al. (2014). Higher dissolved nitrogen content in the soil is associated with high organic matter content, and thus the soil fertility is improved. Suranadi Nature Tourism Park had the highest P availability of all research locations. The high P availability in this location might be caused by the high level of Organic C in the soil. This finding reflects that of Harahap et al. (2020), that the P-element available in the soil can be caused by the presence of organic matter in the soil, either directly or by a mineralization process. Therefore, it can release fixed P.

Nuraksa Forest Park Utilization Block had the highest soil moisture value and soil moisture content, while Nuraksa Forest Park Protection Block had the highest air temperature of all research locations (Table 1). High soil moisture contributes to increased soil moisture because more water is available in the pores of the soil. This condition is also related to the texture of clay soil, which is denser due to the high percentage of dust. Clay soil has a high-water storage capacity, which enables moisture to last longer. According to Herawati et al. (2021) The texture of the soil is smoother (clay soil), has a higher ability to hold water and nutrients compared to sandy soils. Although the ability of the soil to circulate air tends to be lower, its capacity to store water is higher. High soil moisture content coupled with dense soil texture can cause anaerobic conditions and cause washing, precipitation, or P shape changes to become insoluble, leading to a decrease in P and K levels in the soil. According to Wu et al. (2024) Soil compaction reduces porosity which impacts a decrease in the level of P available in the soil and affects the bacterial community of phosphate decomposition and nitrogen fixation, which contributes to a decrease in the availability of P and K.

#### **Relative abundance and potential of soil Collembola as a bioindicator in conservation areas in West Lombok**

The relative abundance of Collembola in soils in conservation areas was used to compare the proportions of genera within an area. Soil Collembola in the conservation areas in West Lombok is comprised of 48 genera, divided into 14 families and three orders (Table 2). This number of genera is higher than that found in research conducted by Widrializa (2016) on four land uses in the Jambi Hope Forest landscape. This difference is thought to be closely related to the individual's ability to adapt to changes in the abiotic environment, such as pH, organic carbon, total nitrogen, and food sources (Widrializa 2016). The Collembola families with the largest number of genera are Entomobryidae, Isotomidae, and Paronellidae. These three Collembola families were found in all conservation areas in great abundance. They are also the most commonly found families in the habitat. These findings are similar to research conducted by Trianto and Marisa (2020) on three land use types in Banjar District, South Kalimantan, and research by Husamah et al. (2016) on three habitat types in the Berantas Watershed in Malang City. According to Erwinda et al. (2016), Entomobryidae and Isotomidae families are in high abundance and can be found in many

places. The natural habitat of Collembola is the soil surface and plant litter (Zuhriah et al. 2023). Entomobryidae are characterized by a slender body and long furcula, so it is able to move very actively and shows the ability to adapt quickly to its environment (Trianto and Marisa 2020). The Entomobryidae family is often found in high populations and plays a role as a decomposer, recycling nutrients in the soil (John et al. 2021).

*Callyntrura* is a genus within the collembolan family with the highest relative abundance, followed by *Lepidosira*, *Coecobrya*, and *Pseudoparonella* (Table 2). These four genera of Collembola have a high abundance and a wide distribution area. Members of these genera are primarily found in surface soils or leaf litter layers and topsoils. *Callyntrura* and *Pseudoparonella* are members of the family Paronellidae, while *Lepidosira* and *Coecobrya* are members of the Entomobryidae family. *Callyntrura* was found in large numbers in three conservation areas, but not in Kerandangan Nature Tourism Park. This might be due to the environmental conditions such as high temperatures, humidity, and low moisture content in the area. According to Suhardjono et al. (2012), *Callyntrura* prefers surface soil habitats with humid environments, especially in tropical and subtropical forests. *Callyntrura* acts as a decomposer of organic matter and cycle nutrients in the soil, which is important in maintaining healthy ecosystem (Yin et al. 2019; Jing et al. 2023).

The highest percentage of abundance of the *Pseudoparonella* was found in Kerandangan Nature Tourism Park and Suranadi Nature Tourism Park, as well as Nuraksa Forest Park Protection Block, but not in Nuraksa Forest Park Utilization Block. *Lepidosira* also showed a high total abundance, but was very low in Nuraksa Forest Park Utilization Block. It is possible that the low percentage of P available and soil CEC caused the non-discovery of *Pseudoparonella* and the low abundance of *Lepidosira* in Nuraksa Forest Park Utilization Block. The results of the study by Widyastuti et al. (2016) showed that the populations of *Pseudoparonella* and *Lepidosira* were positively correlated with the P-content available in the soil. This finding corroborates the finding of Harta et al. (2021), who state that the availability of P and K in soil can influence the abundance and diversity of Collembola. Soils with higher P and K content support a greater abundance of Collembola.

*Pseudosinella* is a genus of the family Entomobryidae. Meanwhile, *Isotomiella* is a genus of the family Isotomidae, and our study found that it had a relatively high percentage and was only found in Kerandangan Nature Tourism Park. This might be due to the adaptability of the two genera to microhabitat conditions that are slightly disturbed in Kerandangan Nature Tourism Park. *Pseudosinella* is a genus of Collembola that can be found in various environmental conditions. The results of Khartika et al. (2021) Research on the genus *Pseudosinella* showed that they were found in large numbers under various conditions, both nocturnal and diurnal, in both shaded and exposed locations. *Pseudosinella* belongs to a small genus, with a body length of 0.6 mm or <1mm. This genus is found in habitats of litter, soil, and caves (Suhardjono et al. 2012). The genus *Isotomiella* is one of

the genera with the highest number of individuals in oil palm plantations (Silaen 2020).

*Mimoderus* (Cyphoderidae), *Proisotoma* (Isotomidae), and *Oudemansia* (Neanuridae) are genera of Collembola found only in Nuraksa Forest Park Utilization Block. They tend to be found in habitats with high humidity, such as

those in Nuraksa Forest Park Utilization Block. These genera love mossy soils, weathered wood, and underground layers rich in organic matter. *Mimoderus* is often found in termite nests (Suhardjono et al. 2012). High humidity supports the survival of the three genera because their bodies are susceptible to drought (Suhardjono et al. 2012).

**Table 2.** Relative abundance of soil Collembola in West Lombok, West Nusa Tenggara, Indonesia, conservation area

Ordo, Family	Genus	Location of conservation areas on the island of Lombok				Total
		Kerandangan Nature Tourism Park (%)	Suranadi Nature Tourism Park (%)	Nuraksa Forest Park Utilization Block (%)	Nuraksa Forest Park Protection Block (%)	
<b>Entomobryomorpha</b>						
Cyphoderidae	<i>Cephalophilus</i>			2.58	0.21	2.8
	<i>Cyphoderopsis</i>			5.16	0.63	5.8
	<i>Mimoderus</i>			9.68		9.7
	<i>Seroderus</i>			0.86	0.21	1.1
Entomobryidae	<i>Acrocyrtus</i>				0.83	0.8
	<i>Alloscopus</i>				0.42	0.4
	<i>Coecobrya</i>	8.47	10.62	4.52	10.83	34.4
	<i>Dicranocentrus</i>	5.08	1.77	0.22	0.83	7.9
	<i>Entomobrya</i>	1.69	7.96	3.44	3.96	17.1
	<i>Heteromurus</i>	8.47	6.19	0.43	12.29	27.4
	<i>Homidia</i>	8.47	10.62	0.86	11.25	31.2
	<i>Lepidocyrtoides</i>			4.52	0.42	4.9
	<i>Lepidosinella</i>				0.42	0.4
	<i>Lepidosira</i>	6.78	29.20	2.15	6.46	44.6
	<i>Pseudosinella</i>	3.39				3.4
	<i>Rambutsinella</i>			0.22	0.42	0.6
	<i>Seira</i>	8.47	0.88	0.65	1.46	11.5
	<i>Sinella</i>	5.08	0.88		0.42	6.4
Isotomidae	<i>Axelsonia</i>	5.08		0.65	2.71	8.4
	<i>Cryptopygus</i>			0.22	0.21	0.4
	<i>Folsomides</i>			0.22		0.2
	<i>Isotomodes</i>			4.09	0.42	4.5
	<i>Pseudotomy</i>	1.69		1.08	2.29	5.1
	<i>Isotomiella</i>	1.69				1.7
	<i>Isotomurus</i>		0.88	1.08		2.0
	<i>Psammisotoma</i>			0.43		0.4
	<i>Proisotoma</i>			10.11		10.1
	Paronellidae	<i>Bromacanthus</i>				0.21
<i>Callyntrura</i>			24.78	10.32	20.83	55.9
<i>Dicranocentroids</i>					0.21	0.2
<i>Lepidonella</i>		5.08	2.65	1.72		9.5
<i>Metacoelura</i>		1.69		2.58	2.08	6.4
<i>Pseudoparonella</i>		28.81	0.88		1.25	30.9
<i>Salina</i>			2.65		0.83	3.5
Oncopoduridae	<i>Harlomillsia</i>			0.22		0.2
	<i>Oncopodura</i>			0.43		0.4
<b>Poduromorpha</b>						
Brachystomellidae	<i>Brachystomella</i>			2.58	14.79	17.4
Neanuridae	<i>Frisea</i>			0.86		0.9
	<i>Gnatholonche</i>				0.21	0.2
	<i>Pseudachorudina</i>			7.53	0.42	7.9
	<i>Pseudachorutes</i>			1.29		1.3
	<i>Oudemansia</i> ,			17.20		17.2
	<i>Onychiurus</i>			0.22	0.21	0.4
Onychiurinae						
<b>Symphyleona</b>						
Heanuridae	<i>Vitromura</i>				0.21	0.2
Arrhopalitidae	<i>Collophora</i>			0.22	0.21	0.4
Bourletiellidae	<i>Bourletiella</i>			0.22	1.88	2.1
Dicyrtomidae	<i>Ptenothrix</i>			0.86		0.9
Katiannidae	<i>Sminthurinus</i>			0.22		0.2
Sminthuridae	<i>Pararrhopalites</i>			0.43		0.4

Although Collembola are only found in specific locations, not in all research sites, they can be used as a bioindicator of regional conditions due to their relatively high abundance. According to Purwanti (2015), bioindicators are a group of organisms whose presence or behavior in nature correlates with environmental conditions, and thus they can be used as indicators of environmental quality. Soil mesofauna, including Collembola, can be used to predict ecological damage in the tropics (Buch et al. 2016). Collembola can occupy various ecological niches with a relatively high number and diversity, and are sensitive to ecosystem changes (Suhardjono et al. 2012). According to Safitri et al. (2022), Collembola have the potential as a biological indicator and a determinant of environmental conditions in a habitat, especially conditions in soil ecosystems. Collembola can be a bioindicator because they are susceptible to habitat changes in structure and community function (Trianto and Marisa 2020). Collembola is a suitable taxon that can be used for the evaluation of the simultaneous response to resource alterations and climate change by soil fauna (Chang et al. 2021). According to Iksan et al. (2019), Collembola in a community can be a sign of good and natural environmental conditions.

*Isotomiella*, *Pseudosinella*, and *Callyntrura* are genera of Collembola that can also be used as bioindicators of environmental conditions with minimal organic C content, total N, and low soil moisture content. The sensitivity of soil Collembola to environmental changes is a determining factor for its existence in nature. An increase in number (*Isotomiella*, *Pseudosinella*) denotes a positive response, while a decrease shows a negative response. Sometimes, they may not be found in one habitat (*Callyntrura*), but in other habitats, the number is abundant. The abundant amount of *Pseudosinella* and *Isotomiella* in a habitat reflects the morphological adaptability to life in soils with small and slender body sizes with short antennae and reduced visual apparatus, it is also reported that *Pseudosinella* adapts well to changes in water content (Susanti et al. 2024). According to Rahayu (2016), Collembola can respond to environmental disturbances with specific patterns. Collembola can indicate soil fertility levels due to the abundance of different soil types in different environmental conditions (Rohyani 2012).

*Mimoderus*, *Proisotoma*, *Pseudachorutes*, *Oudemansia*, and *Pseudoparonella* are the genera of soil Collembolas

that can be used as bioindicators of available P and soil CEC, because the five genera have the highest relative abundance and are found only in areas with environmental conditions where P content is available and soil CEC is low. The genus *Pseudoparonella* is not found in an environment with minimal P and CEC but has a high abundance in areas with different environmental conditions. Collembola, which have a high abundance in disturbed habitat conditions, are categorized as negative bioindicators because organisms living or surviving in extreme conditions highly tolerate environmental changes.

### Structure of soil Collembola community in conservation areas in West Lombok

The structure of the Collembola community in conservation areas in West Lombok provides an overview of the interaction of organisms in an ecosystem in the conservation areas. The results of the analysis showed that the average value of Collembola richness index in all regions was in the high category, with a value above three (Table 3). The richness index, the Evenness index and diversity index relate to the number of species and show a different comparison with the relative abundance index and the dominant index in the number of individuals of a species (Chairunnisa et al. 2022). Balanced interactions tend to favor high species richness. Forms of interaction such as competition, predation between morphospecies groups can affect the survival and diversity of communities. Species richness is influenced by biotic and abiotic factors (Wasis and Sajadad 2024). According to Basna et al. (2017), biotic factors include population growth, interactions between morphospecies in the form of competition and predators, while abiotic factors include humidity, temperature, and altitude of the place, which support the life of soil Collembola.

Soil Collembola abundance refers to the number of Collembola individuals in a unit area. Soil Collembola abundance was found to be the highest in Nuraksa Forest Park Protection Block (480 individuals) and the lowest in Kerandangan Nature Tourism Park (59 individuals) (Table 3). The low abundance of soil Collembola in Kerandangan Nature Tourism Park might be due to less supportive microhabitat conditions, such as soil moisture, moisture content, Organic C, and total N, which exhibited low values.

**Table 3.** Structure of the soil collembola community in the West Lombok, West Nusa Tenggara, Indonesia, conservation area

Parameter community structure	Location of conservation areas in West Lombok			
	Kerandangan Nature Tourism Park	Suranadi Nature Tourism Park	Nuraksa Forest Park Utilization Block	Nuraksa Forest Park Protection Block
Richness (Dmg)	3	3	6	5
Abundance (N)	59	113	465	480
Diversity (H')	2	2	3	3
Evenness (E)	0.88	0.77	0.80	0.73
Dominance (D)	0.1	0.2	0.1	0.1

According to Suin (2018), the presence of Collembola in the soil is influenced by environmental factors such as soil pH, soil moisture, soil temperature, and availability of organic matter. Collembola usually live in very moist soils because they are not drought-tolerant (Geovani et al. 2023). According to Pertiwi et al. (2020) Abundance is also influenced by several limiting factors such as restriction of movement space and predators. Collembola predators are usually larger mesofauna or soil arthropods (Utomo et al. 2019). *Acarina* or mites are an important predator group that determines the size of the Collembola population (Rohyani 2012).

Based on the results of the analysis of the Shannon-Wiener diversity index ( $H'$ ), Collembola diversity in the conservation areas (Kerandangan Nature Tourism Park, Suranadi Nature Tourism Park, Nuraksa Forest Park Utilization Block, and Nuraksa Forest Park Protection Block) was in the medium category with an index value between 2 and 3 (Table 3). This indicates that soil Collembola is evenly distributed and has a good environmental carrying capacity. Furthermore, this category also demonstrates a relatively healthy diversity condition, but is still vulnerable to environmental changes and external disturbances in the region. The medium diversity value category of this soil Collembola is the same as the research conducted (Zuhriah et al. 2023) in the Benang Kelambu Waterfall Natural Tourism Area, Rinjani Geopark, Lombok Island. Collembola diversity is related to the adaptability and availability of food in the ecosystem (Widrializa 2016). According to Trianto and Marisa (2020), the diversity and abundance of Collembola are influenced by the ability to adapt to environmental changes that occur in a habitat. Soil Collembola are highly dependent on their microhabitat (Rohyani 2021). Andersen (2018) noted that differences in microhabitats were related to the abundance and diversity of arthropod species, including Collembola in forest soils.

The evenness index of soil Collembola in all conservation areas studied fell into the high category of above 0.6 or close to one based on Magurran (2012). This suggests that the distribution of soil Collembola individuals is evenly distributed in almost all types. These results also indicate that no genus is too dominant because the Collembola community in the soil is in a balanced and stable state at the location. As stated by Lesthyana et al. (2023), higher values of fauna evenness index indicate an even distribution. The higher the value of the evenness index of a species in a community, the more balanced the distribution pattern of a species in the community, and vice versa (Haneda et al. 2013). The high level of soil fauna evenness index is due to soil fauna communities that have almost the same ability to take advantage of various environmental conditions to maintain their lives (Basna et al. 2017). Inayah et al. (2023) assert that the value of evenness index of a species will affect the value of diversity index. Many species may have a high evenness index, and the number of individual species is almost the same in several locations. Species evenness refers to the species' homogeneity; a low evenness index indicates the dominance of a particular species (Husamah et al. 2016).

The dominance index in all conservation areas was low, with an average value of below 0.2. A low dominance value indicates a balance in the area's ecosystem, which can improve the function of the area. The dominance of one population can decrease another population, further causing a reduction in the population that makes up the community. A decrease in the population that makes up a community also means a reduction in the diversity of the community. As stated by Husamah et al. (2016), dominance causes the diversity to be low or less diverse. Dominance can also occur due to environmental factors such as less varied or limited food types for many Collembola, and, as a result, only one or several types survive by utilizing existing resources (Widrializa 2016).

The research results show that soil Collembola serve as important bioindicators because they are sensitive to microhabitat changes, such as temperature, humidity, pH, and organic matter content. The low organic carbon content in Kerandangan Nature Tourism Park has degraded this area and made it less conducive to Collembola growth compared to other locations. *Isotomiella*, *Pseudosinella*, and *Callyntrura* have potential as bioindicators of low water content, organic carbon, total nitrogen, and soil moisture, while *Mimoderus*, *Proisotoma*, *Pseudachorutes*, *Oudemansia*, and *Pseudoparonella* indicate low phosphorus and Cation Exchange Capacity (CEC).

The Collembola community structure in the West Lombok conservation area is characterized by high species richness, moderate diversity, high evenness, and low dominance, reflecting a stable and healthy community. Therefore, Collembola-based monitoring can complement soil physicochemical analysis in assessing ecosystem health. Collembola should be included in ecosystem monitoring protocols, and further research is needed to understand seasonal dynamics and the long-term impacts of disturbances.

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