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Research Article

Exploration of fungal and lichen diversity in Waitatiri Watershed, Central Maluku: ecological potential

Husnaini Bahri[1,*], Prelly M. J. Tuapattinaya[1], Ritha Lusian Karuwal[1]

Biology Education Study Program, Faculty of Teacher Training and Education, Pattimura University, Street Ir. M. Putuhena, Ambon 97233, Indonesia
**corresponding author:* husnaini.bahri@lecturer.unpatti.ac.id

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ABSTRACT

The Waitatiri Watershed (*Daerah Aliran Sungai/DAS*) in Central Maluku is one of the tropical ecosystems that supports biodiversity, including fungi and lichens. Fungi play a significant role in organic matter decomposition, while lichens serve as bioindicators of air and environmental quality. However, information regarding the diversity of these organisms in the Waitatiri watershed remains limited. This study employed purposive random sampling to explore fungi and lichens in the Waitatiri watershed. Samples were collected from substrates such as living tree trunks, deadwood, bark, rocks, and soil. Initial identification was conducted using digital applications, followed by detailed identification based on relevant scientific literature. Data were analyzed descriptively to describe species types, distribution, and ecological roles. The study identified 10 fungal species from the phylum Basidiomycota and 7 lichen species from the phylum Ascomycota, with foliose thalli and crustose thalli growing on living at tree trunks, dead bark, and rocks. The presence of crustose lichens indicates relatively good air quality in the region. The diversity of fungi and lichens in Waitatiri watershed highlights its importance as a local biodiversity habitat. Their ecological roles as decomposers and environmental bioindicators emphasize the need for watershed ecosystem conservation to ensure environmental sustainability. Further research is required to explore the ecological and economic potential of the identified species and support conservation efforts.

Keywords: biodiversity, ecological, fungi, lichens

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INTRODUCTION

Watersheds (WS) are key ecosystems that play a crucial role in supporting environmental sustainability, especially in tropical regions such as Indonesia. In addition to serving as the primary water source for communities, watersheds also provide habitats for various ecosystems and vegetation, including diverse species of fungi and lichens, which contribute to ecological balance and biodiversity (Putra et al. 2019). Fungi and lichens are essential components of biotic ecosystems that are often overlooked (Mukherjee & Ghorai, 2023). Fungi play a significant role in ecosystems, particularly in the decomposition of organic matter, nutrient cycling, and symbiotic interactions with plants. Meanwhile, lichens, which are symbiotic organisms formed by fungi and algae, serve important ecological functions, including acting as bioindicators of air and environmental quality (Thakur et al. 2024).

Waitatiri Hamlet, located in Central Maluku, Ambon City, is one of the areas with a relatively natural watershed ecosystem. The Central Maluku Regency Central Bureau of Statistics reports that the average monthly temperature ranges from 27.7°C to 28.6°C, with a maximum temperature reaching 34.2°C in April. The high humidity and year-round variable rainfall, influenced by the tropical maritime climate and monsoon winds, create an ideal habitat for various species of fungi and lichens.

Lichens are well known as sensitive bioindicators of air quality changes due to their ability to absorb pollutants directly from the atmosphere through their surface (Thakur et al. 2024). Their presence or absence in an area reflects environmental conditions, such as air pollution levels, the presence of heavy metals, or microclimate changes (Hutasuhut et al. 2021).

Despite its significant biodiversity potential, the exploration of fungal and lichen diversity in the Waitatiri Watershed remains very limited. Information regarding species composition, distribution, and ecological roles has not been comprehensively documented. Globally, an estimated 20,000 species of lichens and lichen-forming fungi exist (Grimm et al. 2021). However, research on lichens in Indonesia remains minimal compared to the country's vast biodiversity, highlighting the need for further exploration and study.

This study aims to identify fungal and lichen species in the Waitatiri Watershed and analyze their ecological roles and potential as environmental bioindicators. By conducting this exploration, the research is expected to contribute significantly to scientific development, particularly in biology and ecology. Furthermore, the findings of this study may serve as a foundation for conservation efforts and sustainable ecosystem management. More in-depth documentation will help reveal local biodiversity while promoting the wise utilization of natural resources.

METHODS

This study employed a purposive random sampling method to collect data on fungal and lichen diversity in the Waitatiri WS, Central Maluku. The site selection was conducted deliberately, considering locations that were deemed representative of fungal and lichen habitats, namely residential areas and riverbanks. These two locations were chosen due to their potential diversity in supporting fungal and lichen growth.

Lichen samples were collected from the bark of living trees and rocks near the river, while fungal samples were taken from various substrates, including dead tree trunks, living tree trunks, and leaf litter on the forest floor. For lichens growing on trees, observations were conducted at a height of 1–3 meters above the ground. Fungal observations were carried out on decaying tree trunks and fallen leaves on the soil surface.

Samples were collected directly from the field using various tools and materials, including ziplock plastic bags for storage, label paper for recording specimen information (species name, habitat, and specimen number), a digital camera for morphological documentation, and a pen for field notes. Morphological documentation was performed before sample collection to facilitate further identification.

Preliminary identification of fungi and lichens was conducted using digital applications such as Google Lens, ShroomID, and the website www.mushroomexpert.com/ to obtain a quick reference of species names. This identification process was further refined using scientific literature and reliable references related to fungi and lichens. Detailed identification was carried out by analyzing key morphological characteristics such as fruiting body structure (fungi), thallus structure (lichen), color, texture, and growth substrate.

The identified species were then analyzed descriptively to provide an overview of fungal and lichen diversity in the Waitatiri Watershed. The data included the species found, their distribution across different habitats, and the ecological characteristics of their growing substrates. This method is expected to provide a comprehensive understanding of the diversity of fungi and lichens inhabiting the Waitatiri Watershed and their ecological potential in maintaining ecosystem balance.

RESULTS AND DISCUSSION

During an intensive field exploration, a total of 10 fungal species and 7 lichen species were successfully collected along the pathways near the Waitatiri River. The fungi and lichens were identified from various substrates, including tree bark, rocks, deadwood, and leaf litter. These findings indicate the presence of diverse fungal and lichen species in the Waitatiri Watershed, highlighting their ecological role in nutrient cycling and environmental bioindication. Results of fungal and lichen exploration in the Waitatiri Watershed, Central Maluku as a Figure1 and Figure 2.

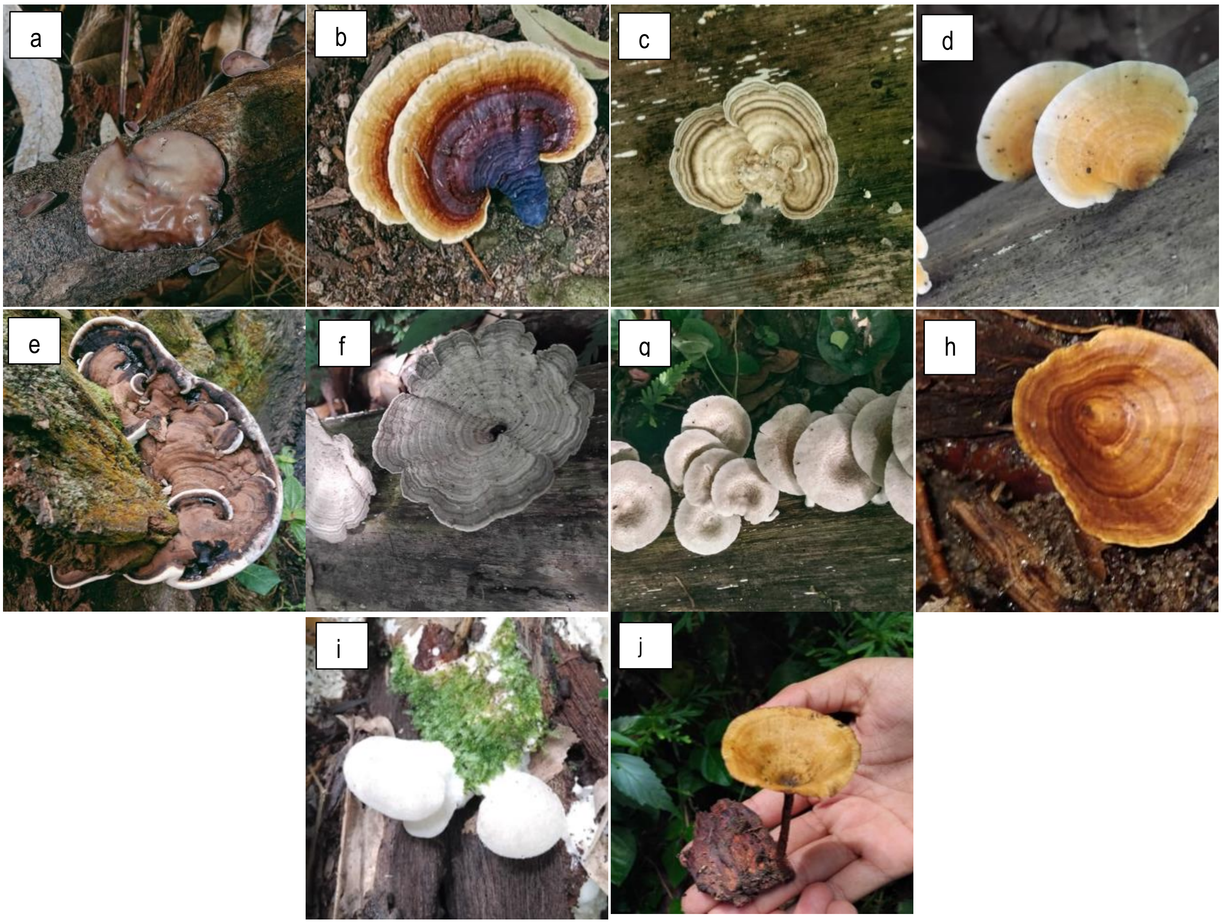

Figure 1. Results of fungal exploration in the Waitatiri WS, Central Maluku. (a) *Auricularia judae*; (b) *Ganoderma lucidum*; (c) *Poronidulus conchifer*; (d) *Stereum ostrea*; (e) *Ganoderma boninense*;(f) *Polyporus sp.;* (g) *Lentinus tigrinus*; (h) *Lignosus rhinocerus*; (i) *Pleurotus ostreatus*; (j) *Amauroderma rude*.

Fungi from the phylum Basidiomycota are the most commonly found group in the exploration results. The following table presents the exploration results and the types of substrates where they grow.

Table 1. Fungal species identified from exploration in the Waitatiri Watershed, Central Maluku

Species	Phylum	Family	Substrate
Auricularia judae	Basidiomycota	Auriculariaceae	Dead wood
Ganoderma lucidum	Basidiomycota	Ganodermataceae	Dead tree trunk
Poronidulus conchifer	Basidiomycota	Polyporaceae	Decaying tree trunk
Stereum ostrea	Basidiomycota	Stereaceae	Dead wood
Ganoderma boninense	Basidiomycota	Ganodermataceae	Base of infected tree trunk
Polyporus sp.	Basidiomycota	Polyporaceae	Dead or decaying wood
Lentinus tigrinus	Basidiomycota	Polyporaceae	Dead or decaying wood
Lignosus rhinocerus	Basidiomycota	Polyporaceae	Soil
Pleurotus ostreatus	Basidiomycota	Pleurotaceae	Decaying branches and trunks
Amauroderma rude	Basidiomycota	Ganodermataceae	Dead or decaying wood

The exploration results indicate that fungal diversity in the Waitatiri Watershed (DAS), Central Maluku, is predominantly composed of species from the phylum Basidiomycota. In this study, 10 fungal species were identified, distributed across various substrates, including dead wood, decaying tree trunks, and soil. These substrates play a crucial role as a growth medium for fungi, providing not only nutrients but also serving as a site for the decomposition of organic matter (Boddy & Watkinson, 1995).

Most of the identified species were found on dead or decaying wood. *Auricularia judae, Stereum ostrea,* and *Amauroderma rude* primarily utilized dead wood as their main habitat, highlighting the significance of deadwood as a substrate that supports fungal life cycles in the Waitatiri Watershed ecosystem. Species such as *Ganoderma lucidum* and *Ganoderma boninense* (family *Ganodermataceae*) were found on dead tree trunks and the base of infected trees. Their presence underscores their role in wood decomposition and as indicators of forest ecosystem health. Ganoderma species are also known for their high ecological and economic value, particularly in pharmaceutical applications.

Additionally, Lignosus rhinocerus demonstrated a different adaptation by growing in soil, whereas *Polyporus sp.* and *Lentinus tigrinus* thrived on decaying wood. These fungi possess the ability to degrade complex organic matter, contributing to the nutrient cycle within the watershed ecosystem. *Pleurotus ostreatus* was observed on decaying tree trunks and branches. As a saprophytic fungus, this species plays an essential role in organic matter recycling and also holds economic value due to its potential for cultivation as an edible mushroom.

The diversity of fungal substrates reflects the ecological heterogeneity of the Waitatiri Watershed, which provides various resources to support fungal survival. From an ecological perspective, fungi play a crucial role in breaking down complex organic matter into simpler compounds that can be readily absorbed and utilized by other organisms. As one of the key biotic components of the ecosystem, fungi act as decomposers, parasites, and mutualistic organisms. During the decomposition process, fungi can break down complex organic compounds such as cellulose, hemicellulose, pectin, starch, and lignin into simpler forms, which are then utilized by other organisms, including bacteria and plants (Geethanjali & Jayashankar, 2016; Nemet et al. 2021).

Furthermore, these exploration findings reinforce the need for sustainable ecosystem management in this region. By documenting the fungal species present, this study provides a foundation for future explorations focusing on the economic and ecological benefits of fungi in the Waitatiri Watershed.

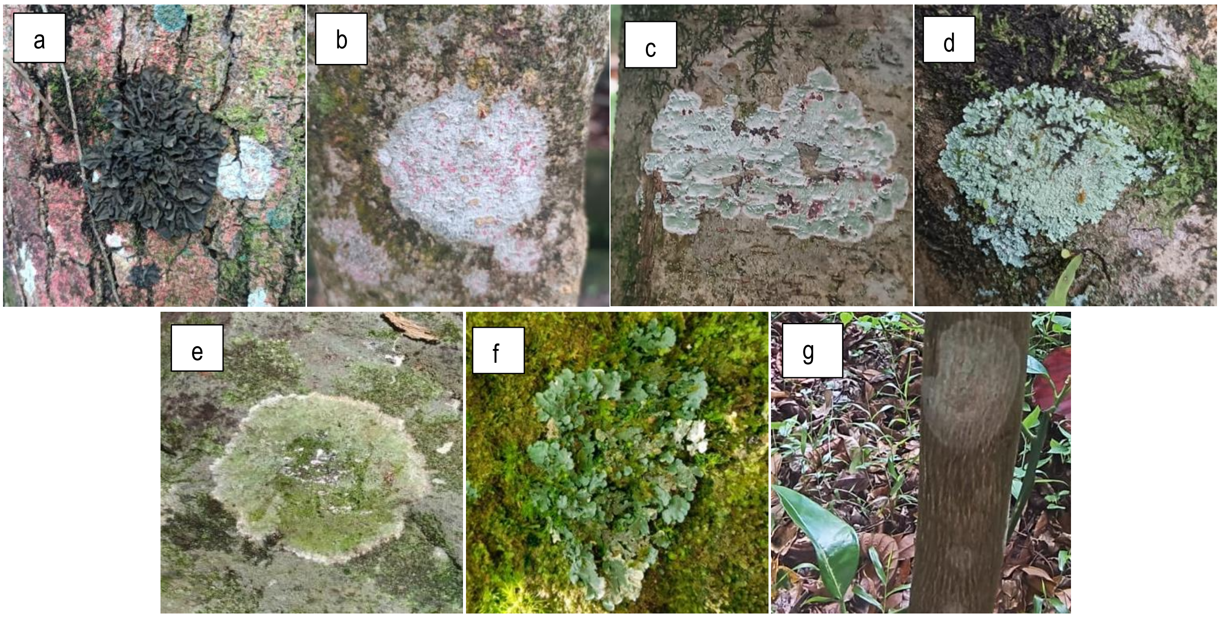

Figure 2. Results of lichen exploration in the Waitatiri WS, Central Maluku (a) *Leptogium cyanescens*; (b) *Herpothallon rubrocinctum*; (c) *Phlyctis sulcata*; (d) *Dirinaria picta*; (e) *Cryptothecia royalty;* (f) *Parmelia saxatilis*; (g) *Cryptothecia striata*

Table 2. Lichen distribution in Waitatiri, Central Maluku

Species	Phylum	Substrate	Thallus Type
Leptogium cyanescens	Ascomycota	Living tree bark and rocks	Foliose
Herpothallon rubrocinctum	Ascomycota	Living tree bark	Crustose
Phlyctis sulcata	Ascomycota	Living tree bark	Crustose
Dirinaria picta	Ascomycota	Tree bark and rocks	Foliose
Cryptothecia royalty	Ascomycota	Dead wood bark and rocks	Crustose
Parmelia saxatilis	Ascomycota	Rocks	Foliose
Cryptothecia striata	Ascomycota	Living tree bark	Crustose

The exploration conducted in the Waitatiri WS (DAS) in Central Maluku identified a diversity of lichens consisting of seven species belonging to the phylum Ascomycota. Foliose-type lichens, including *Leptogium cyanescens, Parmelia saxatilis*, and *Dirinaria picta*, were found on living tree bark and rocks. Meanwhile, crustose-type lichens identified included *Herpothallon rubrocinctum, Phlyctis sulcata, Cryptothecia royalty,* and *Cryptothecia striata*.

Lichens are generally categorized into four primary thallus types: crustose, foliose, fruticose, and squamulose. In this study, only two thallus types were identified: foliose and crustose. This classification was determined based on distinct morphological features. Foliose lichens exhibit a broad, flattened, and lobed thallus with curled edges, resembling leaf structures. Their attachment to the substrate is relatively loose, allowing portions of the thallus to slightly lift from the surface. Additionally, foliose lichens are flexible in texture and can be detached from the substrate with minimal damage. Conversely, crustose lichens are characterized by a thin, compact, and rigid thallus that adheres firmly to the substrate, making separation difficult without causing damage. Their hard and tightly bound texture often forms a thin layer covering surfaces such as rocks, tree bark, or soil. The identification of only foliose and crustose lichens in the study area suggests that these two morphological types dominate the observed ecosystem. Their structural characteristics provide valuable insight into the environmental conditions and substrate preferences within the region (Supriati & Helmiyetti, 2021; Rohim et al. 2024).

Lichens play a crucial ecological role in the Waitatiri Watershed. The presence of foliose and crustose thalli highlights the potential of lichens as bioindicators of air quality. These two thallus types are well-suited to Indonesia's climatic conditions. Observations in the study area indicated that crustose lichens were more dominant than foliose lichens, possibly due to their greater adaptability and ease of growth in the Waitatiri Watershed climate. Although crustose lichens grow more slowly, they are highly resistant to various environmental conditions due to minimal water loss, strong adhesion to substrates, and their homoiomerous thallus structure (Madjeni et al. 2020).

Table 3. Form and color of lichen thallus

Species	Thallus Form	Color Thallus
Leptogium cyanescens	Tends to be round	Brown
Herpothallon rubrocinctum	Tends to be round	Light grayish-green with red spots
Phlyctis sulcata	Irregular	Light grayish-green
Dirinaria picta	Tends to be round	Light green
Cryptothecia royalty	Tends to be round	Green with gray thallus edges
Parmelia saxatilis	Irregular	Green
Cryptothecia striata	Tends to be round	Grayish-green with whote thallus edges

Studies conducted by Kaswinarni et al. (2023) and Nailufa et al. (2021) indicate that lichen thallus color and morphology can change when exposed to air pollution. Lichens tend to turn into a greenish hue with fragmented thalli when exposed to polluted air. Lichens are highly sensitive to air pollution due to their structural composition, which consists of both algae and fungi. Algae contain chlorophyll, which plays a role in photosynthesis, while fungi function in nutrient absorption and responding to environmental changes. The color change in lichen thalli occurs as pollutants from the air are absorbed and accumulated within lichen cells (Aptroot et al. 2014; Roziaty et al. 2023). Based on these findings, there is no indication of a change in thallus color in the lichens observed in Waitatiri. The thallus colors found still correspond to the natural characteristics of each species, such as Leptogium cyanescens, which remains brown, Herpothallon rubrocinctum, which has a light grayish-green color with red spots, and other species that retain their natural colors. Since this study did not find significant color changes in the lichen thalli, this could indicate that the air quality in Waitatiri is still relatively clean and has not been polluted to a level that physiologically affects lichens. However, to confirm this further, additional analysis is needed, such as measuring the heavy metal content in lichen tissues or directly monitoring air quality.

This discovery underscores the importance of the Waitatiri Watershed as a potential lichen habitat. By documenting lichen species and understanding their substrate preferences, this study provides insights into local ecosystem stability and serves as a foundation for further research on bioindication and environmental conservation. The exploration results highlight the significance of the Waitatiri Watershed as a habitat that supports the diversity of fungi and lichens. This species diversity not only provides ecological benefits but also holds potential for sustainable applications in various fields, including agriculture, health, and environmental conservation.

CONCLUSION

The diversity of fungi and lichens found in the Waitatiri WS demonstrates significant potential for the ecosystem and environment. Their role as decomposers and bioindicators highlights the importance of this exploration in efforts to document and protect local biodiversity. Further research is needed to delve deeper into the potential of each species found and to support more effective conservation measures in the area.

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