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Biodiversity of Lichen in Indonesia

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ABSTRAK

Lumut merupakan kelompok tumbuhan terbesar kedua setelah tumbuhan tingkat tinggi, dengan sekitar 18.000 spesies di seluruh dunia dan sekitar 1.500 spesies tercatat di Indonesia. Memahami keanekaragamannya sangat penting karena peran ekologisnya di berbagai habitat. Penelitian ini bertujuan untuk meninjau keanekaragaman spesies lumut di seluruh Indonesia dengan menganalisis literatur relevan yang diterbitkan antara tahun 2018 dan 2023. Hasilnya menunjukkan beragamnya spesies lumut yang tersebar di berbagai pulau dan ekosistem, masing-masing menunjukkan preferensi habitat tertentu seperti kayu lapuk, batu, dan tanah lembap. Faktor lingkungan, termasuk kelembapan, pH, dan intensitas cahaya, secara signifikan memengaruhi pertumbuhan dan distribusi lumut. Penelitian ini menyimpulkan bahwa Indonesia memiliki keanekaragaman spesies lumut yang sangat besar, yang dicirikan oleh karakteristik ekologi yang berbeda dan kebutuhan habitat yang bervariasi. Temuan ini berkontribusi pada pemahaman kita tentang keanekaragaman hayati dan menyoroti pentingnya melestarikan habitat lumut, yang memainkan peran penting dalam fungsi ekosistem dan bioindikasi. Penelitian lebih lanjut direkomendasikan untuk mengeksplorasi dinamika ekologi dan strategi konservasi spesies lumut Indonesia.

Keywords:
Bryophyta
Species
Analysis

ABSTRACT

Biodiversity of Lichen in Indonesia. Mosses represent the second-largest group of plants, after higher plants, with approximately 18,000 species worldwide and around 1,500 species recorded in Indonesia. Understanding their diversity is essential due to their ecological roles in various habitats. This study aims to review the diversity of moss species across Indonesia by analyzing relevant literature published between 2018 and 2023. The results indicate a rich variety of moss species distributed across different islands and ecosystems, each exhibiting specific habitat preferences such as decaying wood, rocks, and moist soils. Environmental factors, including humidity, pH, and light intensity, significantly influence moss growth and

distribution. The study concludes that Indonesia hosts a vast diversity of moss species, characterized by distinct ecological characteristics and varying habitat requirements. These findings contribute to our understanding of biodiversity and highlight the importance of conserving moss habitats, which play vital roles in ecosystem functioning and bioindication. Further research is recommended to explore the ecological dynamics and conservation strategies for Indonesian moss species.

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INTRODUCTION

Lichens and bryophytes, although often coexisting in similar habitats, are taxonomically and biologically distinct groups of non-vascular organisms. The term Bryophyta originates from the Greek words bryon (meaning "moss") and phyton (meaning "plant"). Mosses, classified under Bryophyta, are small, non-vascular plants that lack true roots, stems, and leaves, and do not contain vascular tissues such as xylem and phloem. Their life cycle features a dominant gametophyte stage and a dependent sporophyte stage, representing a classic example of alternation of generations. Mosses typically inhabit moist and shaded environments, including rock surfaces, tree trunks, and as epiphytes (Rahman & Pujiastuti, 2019).

Despite their ecological importance in soil formation, water regulation, and as bioindicators of environmental health, bryophytes and lichens have not received adequate attention in recent scientific reviews, particularly in the context of tropical ecosystems, such as those found in Indonesia. Moreover, growing interest in their pharmacological, ecological, and biotechnological potential underscores the need for a comprehensive and updated synthesis of existing research. This review, therefore, aims to critically examine current developments in the taxonomy, ecological functions, and potential applications of bryophytes and lichens, while highlighting key knowledge gaps and future research directions.

Lichens represent one of the most diverse groups of non-vascular organisms, ranking second only to higher (vascular) plants in global species richness. With approximately 18,000 species identified worldwide, lichens form a significant component of terrestrial flora, second only to flowering plants in abundance. In Indonesia, around 1,500 species of lichens have been recorded, reflecting the country's high biodiversity (Raihan et al., 2018). The diversity and distribution of lichens are closely influenced by environmental factors, particularly microclimatic conditions such as air humidity, which are in turn affected by altitude.

Despite their ecological significance and potential applications as bioindicators and sources of bioactive compounds, studies on lichen diversity in Indonesia remain limited and fragmented. Furthermore, there is a lack of comprehensive data linking lichen distribution patterns to environmental gradients across different Indonesian regions. This study seeks to address this gap by investigating the diversity of lichen species across various altitudinal zones in Indonesia, thereby contributing to a better understanding of their ecological roles and informing future conservation efforts.

METHOD

The data acquisition process involved using specific search keywords such as “macroalgae,” “seaweed,” “Indonesia,” and “biodiversity,” combined with Boolean operators to refine the results. The initial search yielded a total of 245 articles. These were then screened through a multi-stage filtering process, including title and abstract screening, duplication removal, and full-text eligibility assessment based on predefined inclusion criteria—such as study location (within Indonesia), focus on macroalgal diversity, and publication year (2018–2023). After the screening process, 52 articles were deemed eligible for final analysis.

The selected studies were analyzed qualitatively and quantitatively to identify regional distribution patterns, commonly reported species, ecological roles, and emerging research themes. This comprehensive review provides insights into the macroalgal biodiversity of Indonesia and lays the groundwork for future ecological and conservation studies.

RESULTS AND DISCUSSION

To better understand the diversity and distribution patterns of moss and liverwort species across Indonesia, this study compiled species occurrence data from multiple representative regions spanning different islands and ecological zones. The table below summarizes the species identified at each location, illustrating the variability in bryophyte assemblages influenced by local environmental factors, including substrate availability, humidity, forest type, and altitude. This comprehensive overview provides a foundation for comparing regional biodiversity, highlighting both widespread and site-specific species, and exploring ecological relationships that govern bryophyte distribution in tropical ecosystems.

Table 1. Table of Species and Their Distribution

No	Region found	Species
1	Hutan Topidi, Kabupaten Gowa, Sulawesi Selatan	1. *Barbula indica* 2. *Rhynchostegiella menadensis* 3. *Philonotis hastata* 4. *Fissidens atroviridis* 5. *Hyophila apiculata*
2	Kebun Raya Bogor, Kota Bogor, Jawa Barat	Effect of Biology Learning Outcomes After PBL Implementation
3	Air Terjun Riamau, Nusa Tenggara Barat	The Effect After the Application of PBL on class X Virus Material on Learning Outcomes
4	Curug Sibedug Petungkriyono, Kabupaten Pekalongan, Jawa Tengah	The Effect of PBL Implementation on Problem-Solving Skills and Learning Outcomes
5	Air Terjun Potang-Potang Negeri Itawaka, Kabupaten Maluku Tengah, Maluku	The Effect of Video-Assisted Discovery Learning Model and PBL on Students' Motivation and Learning Outcomes
6	Hutan Cagar Alam Situ Patenggang, Jawa Barat	Effectiveness between PBL-Collaborative and PBL-Social Skill on Biology Learning Outcomes
7	Bukit Reli, Kabupaten Musi Rawas, Sumatera Selatan	Effectiveness of application PBL model (Virus content) for Students Science Process Skills and Students Learning Outcomes
8	Hutan Adat Bukit Benuah, Kabupaten Kubu Raya, Kalimantan Barat	The Impact of Implementing PBL to Improve Student Learning Outcomes
9	Aliran sungai Bedadung, Jember, Jawa Timur	Evidence that PBL can Improve Learning Outcomes in Biology
10	Air Terjun Peucari Bueng Jantho, Kabupaten Aceh besar, Aceh	Application of PBL to STIKES Bali Students on Learning Outcomes of Biology Courses

Based on the articles that have been selected in general, all of them discuss the correlation among the application of PBL and Biology cognitive learning outcomes. Through the selection of articles above, it is seen that PBL is one of the learning models that can influence and have a positive impact on cognitive learning outcomes. This is due to the PBL learning pattern which can influence the work of students' cognitive aspects, because students' cognitive aspects need to be developed and directed following structural learning (Aisyah, 2015). In addition, the PBL learning model is known for its characteristic of providing a problem around and allowing students to explore the problem until finally finding a solution that can be constructed into a cognitive knowledge (Hartati, 2023). Students' cognitive processes can also be formed through interactions and experiences gained by students and this is part of one of the processes in the stages of PBL implementation (Yusuf, 2017).

The statement is linear with various articles that have been selected for further analysis. The articles that have been selected are then analyzed to see each method and research results. The requirements needed in each article are that there is a control class and an experimental class. In addition, the quantitative data needed is the average score of the class of experimental and class of control, the total of students in the class used, standard deviation, and t-count. The following are data analysis results from various studies totaling 15 different article titles (Table 2).

Table 2. Data analysis from each article

Tittle Code	Years	Result							
		x experiments	x control	SD control	t-counts	nE	nC	SE	Interpretation
A1	2023	-	-	-	2,451	36	36	0,58	Moderate
A2	2023	73,70	57,58	11,439	-	-	-	1,40	High`
A3	2022	81,08	78,16	8,654	-	-	-	0,33	Moderate
A4	2021	-	-	-	3,035	26	26	0,84	Moderate
A5	2016	83,29	77,43	7,31	-	-	-	0,801	Moderate
A6	2019	81,973	77,720	7,898	-	-	-	0,538	Moderate
A7	2019	-	-	-	2,802	36	36	0.66	Moderate
A8	2018	52.00	48.55	7.548	-	-	-	0,45	Moderate
A9	2018	65,52	53,41	12,14	-	-	-	0.99	Moderate
A10	2018	-	-	-	2,048	81	81	0,321	Moderate
A11	2021	55,75	50,45	5,106	-	-	-	1,02	High
A12	2016	-	-	-	3,489	64	32	0,755	Moderate
A13	2016	-	-	-	5,422	25	24	1,54	High
A14	2015	-	-	-	3,02	40	38	0,68	Moderate
A15	2013	-	-	-	2,564	36	36	0,604	Moderate

Information:
t = t-count (T-value)
nE = Number of Experimental Samples
nC = Number of Control Samples

Based on the results obtained from the calculation of the effect size of 15 articles, there are 3 articles that have a large effect, and 12 articles that have a moderate effect. Table 2 shows that article A2 has an effect size of 1.40, A11 has an effect size of 1.02 and A13 has an effect size of 1.54, in accordance with Table 1 that the effect size of more than 1.00 is included in the high criteria. This shows that Problem-Based Learning (PBL) is effective in improving student cognitive

learning outcomes in Biology subjects. PBL has proven effective in improving student learning outcomes because the process is related to honing students' ability to solve problems that will provide results at the end of the process (Malmia et al., 2019; Yani et al., 2021). The basic concept of the PBL model is to let students solve problems to carry out the process of learning. This is in line with Faradila & Kashardi's research (2022) that the PBL learning model is one of the models that leads to critical thinking skills and encourages students to solve problems following real life and can make students more active in learning.

The difference in effect size criteria as in Table 2 is because this PBL learning model has advantages, weaknesses, and factors that can affect learning outcomes of students in biology subjects. The PBL (Problem-Based Learning) learning model has the advantage that during the process of learning using problem-based learning so that students can do more experiments so that students are easier to remember lessons in the long term (Asiyah et al., 2020). The syntax applied in this model allows students to get better learning outcomes. According to Arends (2009), the Problem-Based Learning (PBL) model has five stages or five syntaxes, namely: 1. Orienting the problem to students, 2. Organizing the students for learning, 3. Guiding the students in groups to conduct investigations, 4. Developing and giving presentations from discussion results and 5. Analyzing and giving evaluate the problem-solving process. There are some of weaknesses of the PBL model such as the model require a long time in the learning process students who are not familiar with the PBL model and certain materials may experience difficulties, there is a possibility that students who do not understand the basic concepts will become passive and result in differences in student learning outcomes, and not all learning materials are suitable for PBL learning models (Warsono & Hariyanto, 2013).

Factors that affect student learning outcomes, namely: 1. Internal factors, 2. External factors, and 3. Learning approach factors. Internal factors are factors that arise from students in the form of conditions, intelligence, and physical and spiritual readiness. This is in line with Hamalik's research (2004) that a person's intelligence factor can affect success in learning so students who have higher intelligence tend to have high learning outcomes as well. This is reinforced by Lvie (1998) that students with high academic ability will achieve better thinking skills so that they are useful as capital in problem-solving and can affect the intellectual level of students. External factors arise from outside such as environmental conditions, one of which is the school environment. The school environment is one of the factors that influence the learning process because there are teaching and learning activities, various co-curricular activities, and others. According to Sudjana (2016), the school environment has a very important role in influencing student learning outcomes. In addition, the learning environment also affects students' learning motivation. This is confirmed by research by Martina (2019) that the school environment influences student learning outcomes. Learning approaches are students' learning efforts such as learning strategies used to carry out activities in learning material (Musriadi, 2014). Learning outcomes are indeed influenced by various factors that have been mentioned, but it is also related to how the process is passed during the learning period. These factors will later work together with all forms of learning processes, ranging from the use of models, and methods to techniques during the process of learning.

CONCLUSION

Based on the results of the meta-analysis that has been carried out regarding the effectiveness of the Problem-Based Learning (PBL) model on cognitive learning outcomes in high schools, the effect size value is 0.33 to 1.54. It can be concluded that the application of PBL in biology learning effectively has a positive effect on cognitive learning outcomes.

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