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ASSESSMENT OF LICHEN DIVERSITY IN SINHGAD FORT AND SURROUNDING AREA

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ABSTRACT
Lichens are promising and amazing form on the earth that exhibit the symbiotic associations between a fungus (mycobiont) and a photosynthetic alga (phycobiont)and exhibiting remarkable ecological adaptation across diverse habitats. The present investigation includes the diversity, distribution of collected Lichens from Sinhagad Fort and its surrounding area. Total of 95 lichen thalli were collected, principally foliose forms, and subjected to morphological identification and authentication at the ARI, Pune. Out of these, 70 specimens were authenticated, including 24 previously reported species and 49 confirmed taxa, among which six species were newly reported from the Sinhagad region.

INTRODUCTION
A fungus (mycobiont) and a photosynthetic partner (phycobiont), form a symbiotic relationship in lichens, which are unusual and captivating organisms. Lichens can thrive in some of the harshest conditions on Earth, from tropical rainforests and urban settings to frozen tundra and deserts, because of their mutualistic relationship. Despite their appearance, lichens are composite creatures that function as a stable biological unit due to the close physiological and structural integration of their partners. As pioneer species, contributors to soil formation, bioindicators of air quality, and suppliers of food and habitat for a variety of organisms, lichens are important to ecosystems. They are thought to make up around 8% of the terrestrial surface of the Earth and are among the earliest known symbiotic systems. Lichens are a significant subject in biological and environmental sciences because of their ecological, economic, and environmental significance (Ahmadjian, 1993).
Over ages, scientific knowledge of lichens has changed. Lichens were categorized with mosses and algae by early naturalists who thought of them as simple plants. The real nature of lichens was not discovered until the middle of the 19th century. The dual hypothesis was put forth by the Swiss botanist Simon Schwendener in 1867. According to this theory, lichens are a hybrid of an alga and a fungus that coexist (Schwendener, 1867). Because of its crust-like appearance on rocks and tree bark, the name "lichen" is derived from the Greek word leikhēn, which means "a scaly eruption." In order to get a deeper understanding of the evolution and categorization of lichens, modern lichenology has extended beyond morphology to include physiological science, chemistry, molecular biology, and ecology (Hawksworth & Hill, 1984). Although some scientists contend that the symbiotic connection in lichens may vary from mutualism to regulated parasitism, it is typically characterized as mutualistic. The fungal companion, which is typically an ascomycete and infrequently a basidiomycete, offers structural support, desiccation prevention, and mineral and water absorption. In exchange, the fungus receives organic food produced by the photosynthetic partner through photosynthesis (Ahmadjian, 1993).
Lichens come in a vast array of shapes and hues. The thallus, or lichen body, is devoid of actual roots, stalks, and leaves. Lichens are often divided into three main categories based on their morphology: Foliose, fruticose, and crustose lichens. The term "lichen" originated from the Greek and refers to the surface growth found on olive tree bark. This group of plants and the term "lichen" were first used by Theophrastus, the

father of botany. Different climates and substrates can support the growth of lichens (Sanjeeva Nayaka 2005). Lichens that grow on tree trunks and bark are known as corticolous lichens; those that live on twigs are termed ramicolous; those that live on wood are called legnicolous; those that grow on rocks and boulders are called saxicolous (epilithic); those that grow on moss are called muscicolous; those that grow on soil are called terricolous; and those that grow on evergreen leaves are called foliicolous (epiphyllous).
Lichens are employed in the discipline of biological monitoring, which uses live organisms to track environmental contamination. Lichen based monitoring is the process of determining the levels of pollutants in the surrounding environment by detecting the amounts of contaminants in lichen tissue. There are different ways to study how the degree of environmental pollution in a certain location has a detrimental impact on the health of lichens there. The physiology of lichen thallus may suffer from the buildup of heavy metals within them. Lichen thallus that has collected heavy metals may experience metabolic pathway disruption and photosynthesis inhibition. The breakdown of chlorophyll is one of the physiological reactions of lichens to heavy metal contamination that is most frequently researched (Puckett K 1976). In lichens, the buildup of heavy metals can induce oxidative stress, which results in the generation of reactive oxygen species and lipid peroxidation (Tarhanen S 1999). A popular indicator of lipid peroxidation, malondialdehyde (MDA) is frequently used to evaluate oxidative stress in lichens exposed to heavy metals (Heath RL 1968; Gonzalez CM). Moreover, lichens' protein content may be impacted by heavy metal buildup, which may result in a reduction in metabolic activity overall. This can have a detrimental effect on lichens' protein content, chlorophyll levels, and lipid oxidation. Nevertheless, no thorough research has been done on which heavy metals directly harm which lichen thalli physiological variable (Conti ME 2001). The physiological reactions of lichens to heavy metal pollution have been extensively studied, however the majority of these investigations have been carried out in controlled settings, such as lab-induced exposure to heavy metals or transplanted lichens (Białońska D 2005; Conti ME 2004; Carreras HA 2002). As a result, little is known about how naturally occurring lichens respond to heavy metals in various settings and whether physiological traits of lichens can serve as markers of varying quantities of heavy metals in these settings. In order to fill this knowledge, we gathered lichens from four distinct natural settings and investigated whether their physiological parameters, such as protein content, MDA content, and chlorophyll degradation could indicate abundance and their lichenometric characteristics.

MATERIALS AND METHODS

Collection and Preservation of Lichen Specimens:

Our investigation included the Collection of Lichen Specimens from the Sinhagad and the peripheral area. Lichen specimens were collected using the standard decorum. We chose to eliminate lichen colonies with a lower biomass, including crustose lichens, due to the significant number of thalli needed for studies.
With the exception of crustose lichens, we collected lichens from the entire sampling region and discovered that they were all foliose lichens. From different places, Sinhagad and the surrounding area, **95** lichen thalli were gathered. Collected specimens were dried at room temperature for a week and stored in a plastic polytene bag for further study.

Authentication of the Collected Lichen Specimen:

The specimens were analysed for morphological characteristics using dissecting and compound microscopes. Photographs were captured both in the field and laboratory for documentation purposes.
Lichen species were identified based on morphological, anatomical, and chemical characteristics. Morphological features were studied under a dissection microscope, while anatomical details of the thallus and fruiting bodies were examined using a compound microscope. Chemical analysis was carried out using colour spot tests and thin-layer chromatography (TLC) following standard protocols.
The specimens were authenticated by Dr. Gargi Pandit and Dr. Bharati Sharma at Agarkar Research Institute, Pune.

RESULTS AND DISCUSSION

Pune district in Maharashtra is the hometown for the amusing diversity of living organism including Lichens. Sinhagad fort and the surrounding area is part of western ghats and having the average annual rainfall of 763 mm and an annual temperature of 25.0°C. During the monsoon and post-monsoon seasons, the significant rainfall in this area produces a large number of transient puddles, ponds, and streams. Tropical dry deciduous forest is the primary natural habitat (Anish Pardeshi et. al. 2021). The distribution of the Lichen within the study area is different with respect to the slope angle and moisture retention of the area.

Table 1. List of collected Lichen Specimens

Sp. No.	Name of the Specimen	Family	Accession No.	Latitude and Longitude
List of collected specimens from the Sinhagad Region, which was previously reported by researcher				
Sp. 1	*Arthothelium awasthii* Patw. & Makhija	Arthoniaceae	--	18.378017 73.776973
Sp. 2	*Buellia indica* S. Singh & D. D. Awasthi	Caliciaceae	--	18.366893 73.754671
Sp. 3	*Buellia palniensis* S. Singh & D.D. Awasthi	Physciaceae	--	18.358292 73.77559
Sp. 4	*Bulbothrix* isidiza (Nyl.) Hale	Parmeliaceae	--	18.365121 73.775773
Sp. 5	*Collema pulcellum* Ach. var. *subnigrescens* (Müll. Arg.) Degel.	Collemataceae	--	18.358307 73.775618
Sp. 6	*Diorygma excipuloconvergentum* Makhija, Chitale & B.O. Sharma	Graphidaceae	--	18.361336 73.773268
Sp. 7	*Graphis polystriata* Makhija & al.	Graphidaceae	--	18.358301 73.775629
Sp. 8	*Hemithecium epixanthum* (Mont. & Bosch) Chitale & Makhija	Graphidaceae	--	18.3613 73.773255
Sp. 9	*Hemithecium nakanishianum* (Patw. & C. R. Kulk) Makhija & A. Dube	Graphidaceae	--	18.358285 73.775628
Sp. 10	*Hemithecium norstictum* Makhija & A. Dube	Graphidaceae	--	18.358207 73.775686
Sp. 11	*Heterodermia angustiloba* (Mull. Arg.) D.D. Awasthi	Physciaceae	--	18.36677 73.755059
Sp. 12	*Heterodermia diademata* (Taylor) D. D. Awasthi	Physciaceae	--	18.361336 73.773268
Sp. 13	*Hyperphyscia syncolla* (Nyl.) Kalb	Physciaceae	--	18.361336 73.773268
Sp. 14	*Lecanora cf. imshaugii* Brodo	Lecanoraceae	--	18.361336 73.773268
Sp. 15	*Leptogium propaguliferum* Vain	Collemataceae	--	18.358296 73.775614
Sp. 16	*Leptogium subazureum* A. Dube & Makhija	Collemataceae	--	18.358182 73.775795
Sp. 17	*Parmotrema austrosinense* (Zahlbr.) Hale	Parmeliaceae	--	18.361336 73.773268

Sp. 18	*Parmotrema sancti-angelii* (Lynge) Hale	Parmeliaceae	--	18.358292 73.77559
Sp. 19	*Phaeophyscia fumosa* Moberg	Physciaceae	--	18.358228 73.775618
Sp. 20	*Phaeophyscia pyrrhophora* (Poelt) D.D. Awasthi & M. Joshi	Physciaceae	--	18.358207 73.775686
Sp. 21	*Physcia abuensis* D.D. Awasthi & Singh	Physciaceae	--	18.366866 73.75334
Sp. 22	*Physcia tribacia* (Ach.) Nyl.	Physciaceae	--	18.366903 73.753422
Sp. 23	*Physcia tribacoides* Nyl.	Physciaceae	--	18.358288 73.775564
Sp. 24	*Pyxine berteriana* var. *himalaica* D.D. Awasthi	Caliciaceae	--	18.358292 73.77559
List of collected specimens from the Sinhagad Region				
Sp. 25	*Arthothelium deplanatum* (Mull Arg.) Makhija & Patw.	Arthoniaceae	AMH 23.150	18.358112 73.776697
Sp. 26	*Caloplaca cerina* (Ehrh. ex Hedw.) Th. Fr.	Teloschistaceae	AMH 23.169	18.368301 73.776629
Sp. 27	Caloplaca *flavorubescens* (Huds.) J.R. Laudon	Teloschistaceae	AMH 23.151	18.364699 73.756454
Sp. 28	*Caloplaca herbidella* (Nyl. ex-Hue) H. Magn.	Teloschistaceae	AMH 23.162	18.358292 73.77559
			AMH 23.167	18.358307 73.776618
			AMH 23.192	18.365659 73.753028
			AMH 23.193	18.361676 73.754007
Sp. 29	*Caloplaca inconspecta* Arup	Teloschistaceae	AMH 23.174	18.365516 73.754879
			AMH 23.198	18.361336 73.773268
Sp. 30	*Caloplaca vitellinula* (Nyl.) H. Oliver	Teloschistaceae	AMH 23.184	18.366898 73.753402
Sp. 31	*Buellia sp.*	Caliciaceae	AMH *23.205*	18.362058 73.753748
Sp. 32	*Dermatocarpon vellereum* Zschacke	Verrucariaceae	AMH 23.207	18.368016 73.753015
Sp. 33	*Diploschistes rampoddensis* (Nyl.) Zahlbr.	Graphidaceae	AMH 23.155	18.367923 73.752958
			AMH 23.159	18.358285 73.77563
			AMH 23.177	18.36173 73.753802
			AMH 23.178	18.365479 73.755116

			AMH 23.199	18.366903 73.753422
			AMH 23.181	18.35828 73.775618
Sp. 34	*Heterodermia pseudospeciosa* (Kurok.) W. L. Culb.	Physciaceae	AMH 23.171	18.361336 73.773268
			AMH 23.176	18.358112 73.776697
			AMH 23.185	18.368301 73.776629
Sp. 35	*Heterodermia speciosa* (Wulfen) Trevis.	Physciaceae	AMH 23.196	18.364699 73.756454
Sp. 36	*Lecanora* sp. B	Lecanoraceae	AMH 23.156	18.358292 73.77559
Sp. 37	*Leptogium azureum* (Sw.) Mont.	Collemataceae	AMH 23.667	18.358307 73.776618
Sp. 38	*Leptogium javanicum* Mont.	Collemataceae	AMH 23.195	18.365659 73.753028
Sp. 39	*Parmotrema tinctorum* (Nyl.) Hale	Parmeliaceae	AMH 23.158	18.361676 73.754007
			AMH 23.170	18.365516 73.754879
			AMH 23.165	18.361336 73.773268
Sp. 40	*Pertusaria* cf. *depressa* (Fee) Mont. et Bosch	Pertusariaceae	AMH 23.168	18.366898 73.753402
			AMH 23.188B	18.362058 73.753748
Sp. 41	*Phaeophyscia hispidula* (Ach.) Moberg	Physciaceae	AMH 23.175	18.368016 73.753015
			AMH 23.201	18.367923 73.752958
			AMH 23.203	18.358285 73.77563
Sp. 42	*Pyxine petricola* var. *petricola* Nyl.	Caliciaceae	AMH 23.183	18.36173 73.753802
			AMH 23.200	18.365479 73.755116
Sp. 43	*Diploschistes sp.*	Graphidaceae	AMH *23.665*	18.366903 73.753422
Newly Reported from Sinhagad				
Sp. 44	*Peltula placodizans (Zahlbr.) Wetmore*	Physciaceae	AMH 23.173	18.363119 73.762679
Sp. 45	*Peltula obscurans* (Nyl.)	Physciaceae	AMH 23.188A	18.358284 73.77563
Sp. 46	*Peltula cataractae* (Büdel & Sérus.) Büdel, Kauff & Bachran	Physciaceae	AMH 23.182	18.361336 73.773268

Sp. 47	*Lecanora cf. xylophila*	Lecanoraceae	AMH 23.161	18.361336 73.773268
			AMH 23.163	18.358292 73.77559
			AMH 23.190	18.361336 73.773268
			AMH 23.179	18.35825 73.77563
			AMH 23.189	18.361728 73.753852
Sp. 48	*Arthothelium saxicola* Makhija & Patw.	Arthoniaceae	AMH 23.153	18.358281 73.775628
			AMH 23.154	18.358168 73.775693
			AMH 23.180	18.358217 73.775653
			AMH 23.187	18.35826 73.775616
			AMH 23.194	18.358112 73.775696
Sp. 49	*Parmotrema saccatilobum* (Taylor) Hale	Parmeliaceae	AMH 23.166	18.363119 73.762679

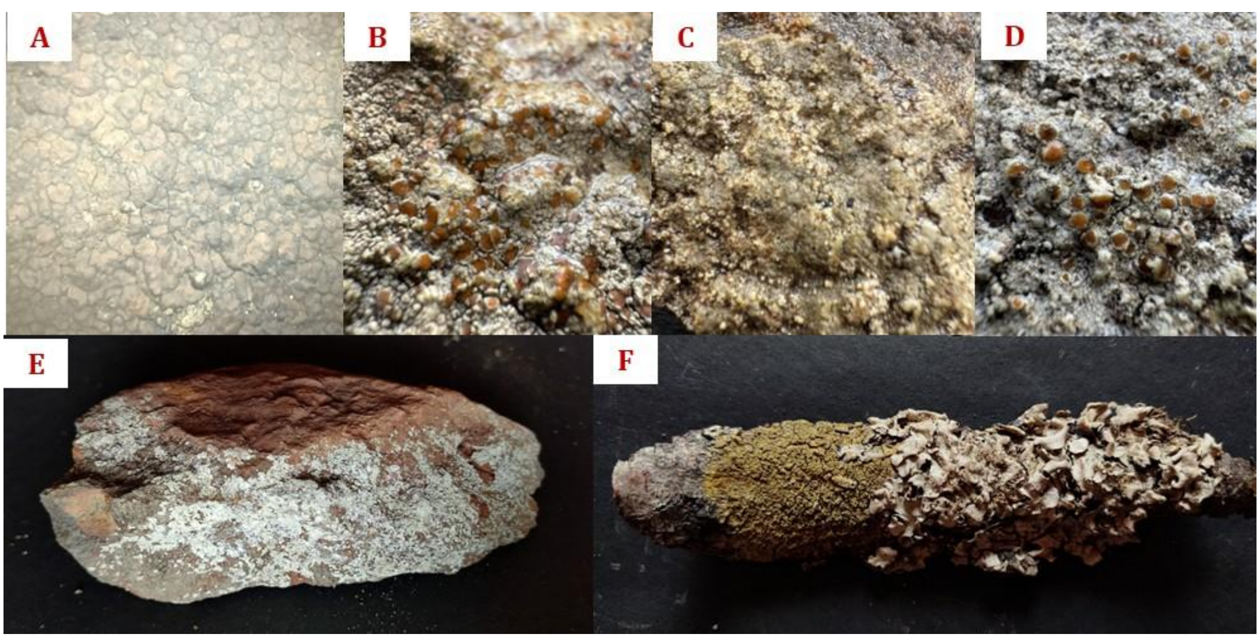


Figure 1. Images of lichen which are newly reported at Sinhgad Region A. *Peltula placodizans (Zahlbr.) Wetmore;* B. *Peltula obscurans* (Nyl.); C. *Peltula cataractae* (Büdel & Sérus.) Büdel, Kauff & Bachran*;* D. *Lecanora cf. xylophila;* E. *Arthothelium saxicola* Makhija & Patw F. *Parmotrema saccatilobum* (Taylor) Hale

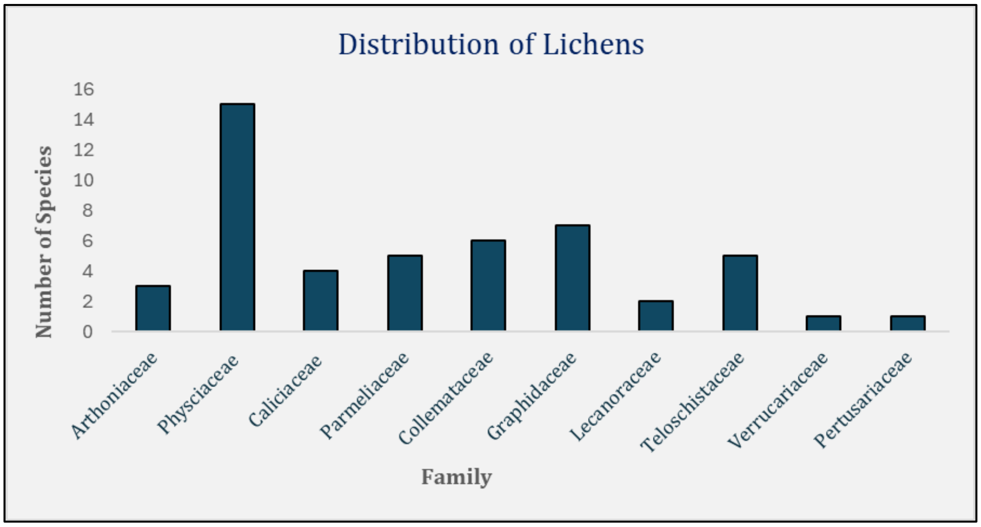
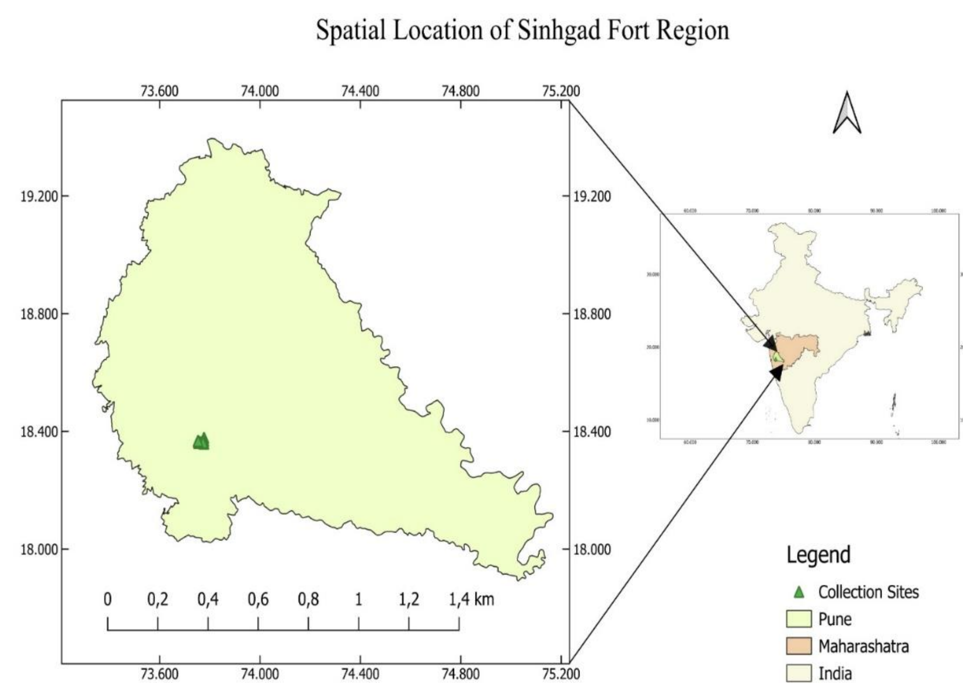


Figure 2. Distribution of Family with Respect to the Lichen Species



The collected 95 lichen specimens were documented with the help of morphological observation. These collected specimens submitted to ARI, out of the 95 submitted specimen 70 were authenticated by the experts, and the accession numbers were written in the table no 1. As per the report obtained from the ARI, out of 95 specimens, 24 specimens were previously reported from the Sinhagad region, and the remaining

specimens were authenticated and obtained the accession number. Out of these 49 authenticated specimens, 6 specimens were newly reported from the Sinhagad region.
Physciaceae is the most prevalent species with the number of fifteen, followed by Graphidaceae i.e. seven species, and Collemataceae with six species. Caliciaceae comprises four species, whilst Parmeliaceae and Teloschistaceae both give five. Lecanoraceae has two species, while Arthoniaceae has three. With only one species each, Verrucariaceae and Pertusariaceae have the lowest representation, suggesting an unequal distribution.

Distribution of Lichens:

There is a noticeable change in the species richness of lichens among families. With the greatest number of species, Physciaceae is the dominant family, demonstrating its remarkable ecological adaptability and broader range of habitats. Additionally, Graphidaceae and Collemataceae show considerable diversity and provide substantial contributions to the total abundance of lichens. Families like Verrucariaceae and Pertusariaceae exhibit low representation, which may indicate limited adaptability or constrained ecological niches. In general, the distribution is unequal, with some families being quite prominent and others remaining uncommon. This demonstrates how lichen variety in the area under study is shaped by environmental factors, substrate availability, and evolutionary adaptability.

CONCLUSION

The study shows that the Sinhagad region has a wide diversity of lichens, with six recently reported species in Sinhagad, with the main family being Physciaceae. Environmental impacts are shown in uneven distribution. Lichens have a great deal of potential as bioindicators since their physiological characteristics can accurately show environmental stress and help with ecological monitoring and biodiversity evaluation.

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