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Identification and Diversity of Lichen Species in Lake Leonard, New Leyte, Maco, Davao De Oro Province

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A B S T R A C T

This study aimed to collect, classify, and identify lichens found in Lake Leonard, New Leyte, Maco, and Davao de Oro Province. Field surveys and sample collection were carried out through the transect walk method. The lichen species were collected using a knife and then placed inside resealable plastic bags. The collected specimens were air dried and then placed on herbarium packets with detailed taxonomic information. The collected specimens were preserved. Out of thirty-five (35) specimens collected, Thirty-three (33) species of lichens were identified. Nineteen (19) genera and twelve (12) families, namely: Pertusariaceae, Physciaceae, Parmaliaceae, Collenmataceae, Graphidaeceae, Cladoniaceae, Teloschistaceae, Coccoatpiaceae, Ramalinaceae, Hygrophoraceae, Thelotremataceae, and Sterocaulaceae Most of the collected species in the study area were rare (73%). Only a few were found widespread in the study area. This result could serve as baseline data for the management of the lichen ecosystem in the area.

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INTRODUCTION

Many urban areas in Mindanao regions face environmental problems such as pollution and the heat effect on island. With the extent of assessing atmospheric changes – organisms (bio indicators) their responds to environmental changes indicates the health condition of the ecosystem. Largest record of bio indicators have appealed considerable attention due to extreme changes of atmospheric conditions. Bryophytes are one such group of plants known to be sensitive to environmental changes, in particular to atmospheric conditions. Their significant in the environment helps to evaluate and assess the effect of environmental changes on the ecosystem.

Lichens are non-vascular plants that are in associations of green algae and fungus that grows in a symbiotic relationship. The fungus receives food from its photosynthetic partner, the phycobiont, the algae; and the fungi, the mycobiont, in turn, provides a suitable habitat and help sorb and retain water and minerals (Campbell, 2000). There are about 20,000 species of lichens worldwide and only 14,000 of the species are names (Rambold 2011).

In the Philippines, there are about 1,108 taxa distributed in 137 era, 786 species and 253 varieties (Azuelo et al., 2011). Apparently, not until the advent of microscopes in the 18th century, lichens were properly studied in terms of anatomical structures where their special dual character was revealed; they mistakenly described earlier as types of mosses or seaweeds (Mulligan, 2009). Epiphytic lichens are extremely sensitive to environmental imbalance. In fact, they have n identified as valuable indicators of environment air quality since as early as 1866 (Kricke Loppi 2002); consequently, they are considered as good indicators of pollution and climate change. Other species of lichens were used in herbal medicine, some plays as "keystone" species mineral cycling, and regulation of microclimate in the forest canopy, and provide food and habitat for host of invertebrates (Russel, 1979; Shevrock, 2001; Azuelo et al., 2011).

This research aims to study identification and diversity of Lichen Species in Lake Leonard, New Leyte, Maco, Davao De Oro Province, which may provide valuable information regarding its biodiversity. Studies on lichens in the Compostela Valley, which is currently known as Davao de Oro, are rare to find. Hence, the researcher aims to examine species diversity and the distribution of lichens in one of its mountains, Lake Leonard is a small freshwater crater lake in Mount Leonard (also known as Leonard Kniaseff), an andesitic-to-dacitic stratovolcano complex in the Leonard Mountain Range. However, climate change may have affected its vegetation, such as lichens' distribution and species diversity (traveltothephilippines.info, 2014).

Worldview and Theoretical Lens

This theory is also anchored on Ecological Niche Theory by Hutchinson, who developed it in 1957 (Takola & Schielzeth, 2021). A niche is a phrase used in ecology that refers to the behavior of a species that lives in a certain habitat (Pulliam, 2000; Leibold, 1995). The ecological niche defines how an organism or population reacts to resource and competition distribution (Chase & Leibold, 2003; Kearney, 2006). The Ecological Niche Theory expresses the relationship of an individual or organism to all aspects of its environment. The ecological niche comprehends all conditions necessary for an organism to exist (Khatibi & Skeikholeslami, 2016). The said theory by Hutchinson (1957) is applied in this study because the niche of lichens may be affected by various environmental factors, including that anthropogenic activities. Likewise, the condition of the other organisms in the ecosystem could be reflected by the lichen distribution and species composition in the area.

On the other side, the Geographical Range of a species may be seen as a geographical mirror of its niche. Along with the qualities of the geographical template and the species that determine its ability to colonize the environment, a species' geographic range is the region it covers when environmental circumstances are good and there are no obstacles to disseminate or colonize (Gaston, 2003; Baillie et al., 2004). When a species is challenged with biotic interactions or abiotic constraints that restrict its dispersion, it will be limited within its realized geographic range (Shaw et al., 2003; Sheth et al., 2008; Sergio et al., 2007). Due to some barriers or constraints, lichen distribution and its diversity may be limited to a specific geographic range.

LITERATURE REVIEW

This section presents readings from the related literature, different books, journals, and articles of different authors relevant to the present research work. The researcher focuses on the study in identification and diversity of Lichen Species in Lake Leonard, New Leyte, Maco, Davao De Oro Province.

Ecological Classification

An ecological classification of lichens based on the influence of moisture would be rather limited as the most lichens are essentially xerophytes. Species of Leciidea, Parmelia, Lecanora and Xanthoria are common on rocks and soil of our driest and warmest regions. A few are strictly aquatic forms (hydrophytes) while a fair number are mesophytes. Some species of Lecanora, Collema, Leptogium andRhizocazrpon are peculiar to wet rocks along streams. A limited number of lichens might be regarded as mesophytes since they live mainly on moist soil, usually in deep shaded woods, cool shaded cliffs and damp soil among mosses. Species of Peltigera are representatitive of these forms (Ejem, L.A. 2005)

The Lichen Flora: Its Distribution, Classification, Morphology, Ecology and Significance

Lichens are non-vascular plants in associations with green algae and fungus that grow in a symbiotic relationship. The fungus receives food from its photosynthetic partner, the phycobiont, the algae, and the fungi. The mycobiont, in turn, provides suitable habitat and helps sorb and retain water and minerals (Campbell, 2000). There are about 20,000 species of lichens worldwide, and only 14,000 of the species are names (Rambold 2011). In the Philippines, there are about 1,108 taxa distributed in 137 eras, 786 species, and 253 varieties (Azuelo et al., 2011). Apparently, lichens were not fully researched in terms of anatomical features until the 18th century, when their distinctive dual nature was found; they were previously misidentified as forms of mosses or seaweeds (Mulligan, 2009).

Epiphytic lichens are particularly sensitive to changes in their environment. They have been recognized as useful indicators of ambient air quality since 1866 (Kricke Loppi 2002); as a result, they are good markers of pollution and climate change. Other lichen species have been used in herbal medicine; some act as "keystone" species in mineral cycling and microclimate management in the forest canopy, as well as providing food and shelter for a variety of insects (Russel, 1979; Azuelo et al., 2011). Furthermore, Türk and Erschbamer (2010a, 2010b) identified 31 lichens growing on soil, plant debris, and terricolous mosses from the neighboring Rotmoosferner and discovered the similar trend of lichen diversity in relation to moraine age. Also, Giordani & al. (2012) demonstrated that lichen functional traits are correlated with the main climatic and anthropogenic gradients, while Rapai et al. (2012) demonstrated that lichen traits explain a considerable amount of variation in community assemblage along a high elevation gradient.

A lichen is made up of a basic photosynthesizing cell, often a green alga or cyanobacterium, that is surrounded by fungal filaments. The majority of a lichen's mass is made up of interwoven fungal filaments, except in filamentous and gelatinous lichens. The fungus is known as a mycobiont. A photobiont is a photosynthesizing organism. Phycobionts are algal photobionts. Cyanobionts are photobionts of cyanobacteria (Shevrock, 2001;). The thallus is the component of a lichen that is not engaged in reproduction, often known as the "body" or "vegetative tissue" of a lichen (Campbell, 2000). The thallus form is distinct from any other form in which the fungus or alga develops individually. The thallus is made up of hyphae, which are fungal filaments (Kricke Loppi 2002). The filaments expand by branching and then reuniting to form a "anastomose" mesh. Fungal filament mesh may be thick or loose ((Mulligan, 2009).

The fungal mesh generally surrounds the algal or cyanobacterial cells, frequently encapsulating them inside complex fungal tissues peculiar to lichen associations. The thallus may or may not have a protective "skin" of tightly packed fungal filaments, which is sometimes accompanied by a second fungus species known as a cortex (Rambold 2011). One cortical layer wraps around the "branches" of fruticose lichens. Foliose lichens feature an upper cortex on the top side and a distinct lower cortex on the bottom side of the "leaf." Crustose and squamulose lichens have just an upper cortex, with the lichen's "interior" in direct touch with the surface on which it grows (the substrate). Even though the edges peel off from the substrate and seem flat and leaf-like, unlike foliose lichens, they lack a bottom cortex (Kricke Loppi 2002). Filamentous, byssoid, leprose, gelatinous, and other lichens lack an ecorticate cortex. Diagram of a foliose lichen cross-section: The cortex is the outer layer of fungal filaments that are closely intertwined (hyphae). Green algae photosynthesize in this photobiont layer. In the medulla, hyphae are loosely packed. Lower cortex that is tightly woven. Rhizines are anchoring hyphae where the fungus connects to the substrate (Campbell, 2000).

Fruticose, foliose, crustose, and squamulose lichens contain up to three distinct kinds of tissue, which are distinguished by the density of fungal filaments. The top layer of the lichen, where it comes into touch with the environment, is known as the cortex. The cortex is made up of fungal filaments that are tightly woven, packed, and glued together (agglutinated) (Toohey, 2014). Because of the thick packing, the cortex acts as a protective "skin," keeping other species out and lowering the intensity of sunlight on the layers underneath. The thickness of the cortical layer may range from a few hundred micrometers (m) to several hundred millimeters (m) (less than a millimeter). In certain lichens, the cortex is topped by an epicortex containing secretions rather than cells that is 0.6–1 m thick (Negi & Upreti, 2000). Pores may or may not exist in this secretory layer. The photobiontic layer, also known as the symbiont layer, is located underneath the cortical layer. The photosynthetic partner is incorporated in less densely packed fungal filaments in the symbiotic layer. Similar to the architecture of a leaf, the less dense packing allows for air movement during photosynthesis (Muggia et al.2011). Each photobiont cell or group of cells is normally individually enveloped by hyphae and, in certain circumstances, punctured by a haustorium. Algae in the photobiontic layer are dispersed amid the fungal filaments in crustose and foliose lichens, diminishing in gradation into the layer below. The photobiontic layer of fruticose lichens is unique from the one underneath (Shevrock, 2001;).

The medulla is the layer that lies underneath the symbiotic layer. The fungal filaments in the medulla are less densely packed than in the layers above. In foliose lichens, such as Peltigera, there is generally additional tightly packed layer of fungal filaments known as the lower cortex (Stocker-Wörgötter & Elix 2009). Rhizines, which are root-like fungal structures, sprout from the lower cortex to adhere or anchor the lichen to the substrate. A single cortex wraps around the "stems" and "branches" of fruticose lichens (Manlove & David, 2015). The medulla is the lowest layer and may be empty or create a cottony white inner core for the branchlike thallus (Christensen, 2014). The medulla of crustose and squamulose lichens is in close touch with the substrate on which the lichen develops because they lack a lower cortex (Campbell, 2000). The margins of the areolas peel up from the substrate and look leafy in crustose, areolate lichens. The section of the lichen thallus that is not connected to the substrate may also seem leafy in squamulose lichens. These leafy sections, however, lack a lower cortex, which distinguishes crustose and squamulose lichens from foliose lichens. Foliose lichens, on the other hand, may seem flattened on the substrate, similar to crustose lichens. Most leaf-like lobes, however, can be removed from the substrate because they are separated from it by a densely packed lower cortex (Gradstein et al., 2003).

Gelatinous, byssoid, and leprose lichens lack a cortex (are ecorticate) and have mostly undifferentiated tissue, akin to having just a symbiotic layer (Ardelean et al., 2015). Cyanobacteria may be stored on the top or lower surface of lichens that incorporate green algal and cyanobacterial symbionts in microscopic pustules termed cephalodia. Pruinia is a white coating that forms on the top of an upper surface. A sticky dead fungal hyphae layer with unclear lumina in or near the cortex above the algal layer is referred to as an epinecral layer. Lichens may take on a variety of shapes and forms (morphologies). The arrangement of the fungal filaments typically determines the morphology of a lichen. The thallus refers to the non-reproductive tissues or vegetative bodily components (Ellis, 2012). Lichens are classified according to their thallus type since the thallus is generally the most visible feature of the lichen. Thallus growth forms are usually associated with a few fundamental internal structural kinds. Common names for lichens are often derived from a lichen genus's characteristic growth shape or color (Campbell, 2000).

Common groupings of lichen thallus growth forms are: fruticose – growing as a tuft or multiple-branched leafless mini-shrub, upright or hanging down, 3-dimensional branches with nearly round cross-section (terete) or flattened; foliose – growing in 2-dimensional, flat, leaf-like lobes, crustose – crust-like, adhering tightly to a surface (substrate) like a thick coat of paint; squamulose – (Gradstein et al., 2003).

Because of differences in growth types within a single lichen species, grey regions between growth type descriptions, and overlapping growth types, various writers may describe lichens using distinct growth type descriptions (Zuga, 2013). When a crustose lichen ages, the center may split up like old-dried paint, cracked asphalt pavement, or polygonal "islands" of cracked-up muck in a dry lakebed. This is referred to as rimose or areolate, and the "island" parts separated by the fissures are referred to as areolas. The areolas seem to be isolated, but they are (or were) linked by an underlying "prothallus" or "hypothallus" (George, 2016). A crustose placodioid lichen is one that develops from a core and seems to radiate out. Squamulose occurs when the margins of the areolas rise off the substrate (Campbell, 2000). These classes of growth forms are not properly characterized. Foliose lichens may branch and resemble fruticose at times. Fruticose lichens may have leafy branching sections and flattened branching parts. Where the margins lift, squamulose lichens may emerge. When dried, gelatinous lichens may resemble leafy. In these circumstances, methods for distinguishing them are provided in the sections below (Mulligan, 2009).

Structures involved in reproduction are often visible on the surface of the thallus as discs, lumps, or squiggly lines (Sejpal, 2013). The thallus is not necessarily the most visually prominent feature of the lichen. Some lichens (endolithic lichens) may grow within solid rock between the grains, with just the sexual fruiting component visible growing outside the rock. These may be eye-catching in terms of color or appearance (Rajan et al., 2016). These sexual components' forms are not included in the growth form groups listed above. Circular, elevated, plate-like, or disc-like outgrowths with crinkly borders are the most visible reproductive components. Lichens come in a variety of hues. The photosynthetic component is generally responsible for color (Daries, 2011). Unique pigments, such as yellow usnic acid, give lichens a wide spectrum of hues, including reds, oranges, yellows, and browns, particularly in sensitive, dry environments. Lichens are often bright green to olive-gray while wet and gray or grayish-green to brown when dried in the absence of distinctive colors.

Because moisture causes the surface skin (cortex) to become more translucent, the green photobiont layer is exposed (Campbell, 2000).

Furthermore, Ravera et al. (2020) discovered that sexually reproducing lichen species always have considerable turnover, while vegetative species tend to form nested assemblages, particularly in old-growth forests. According to Geiser and McCune (1997), phenotypic traits such as thallus morphology, architecture, reproductive structures (e.g., isidia, soredia, apothecia, the fungal spore form and size), and chemistry play an important part in distinguishing lichen species. It's simpler to imagine it in lichens, which are only dispersed by fungal spores. Rikkinen (2002), on the other hand, proposed that lichen species that spread primarily or exclusively by vegetative propagules (asexual lichens) constitute a source of photobionts for spore-dispersed lichens (sexual lichens).

Different colored lichens covering vast sections of exposed rock surfaces or lichens covering or hanging from the bark may provide for a beautiful spectacle when the patches of various colors "spring to life" or "glow" in vivid displays after rain (Campbell, 2000). Depending on the angle of exposure to light, various colored lichens may occupy different nearby portions of a rock face. A lichen's color varies depending on whether it is moist or dry. Identification color descriptors are based on the color that appears when the lichen is dry (Brown & Atkins, 2011). Dry lichens with cyanobacterium as a photosynthetic partner are often dark grey, brown, or black in color. The underside of foliose lichens' leaf-like lobes has a different color from the top side (dorsiventral), commonly brown or black, but rarely white. A fruticose lichen may have flattened "branches" that resemble foliose lichens, but the underside of a fruticose lichen's leaf-like structure is the same color as the top side. A foliose lichen's leaf-like lobes may branch, giving it the appearance of a fruticose lichen, however the underside will be a different color from the top side. Mucilaginous secretions are responsible for the shine of certain jelly-like gelatinous lichens (Aschenbrenner et al., 2014).

Lichens are often used to assess air quality and climate change. They are an efficient early warning system for detecting heavy metal and radioactive material buildup in terrestrial ecosystems (Aptroot & van Herk, 2007). Their usage as environmental phytometers is owing to their unique ecological and physiological needs, which make them extremely sensitive to environmental changes and hence effective indicators of ecosystem health (Boonpragop & Polyiam, 2007). (Gradstein et al., 2003; Aptroot & van Herk, 2007; Wolseley, 2002). They are a crucial component of the intricate web of life, and their extinction has a significant impact on the natural equilibrium. Despite their significance in nature, however, their conservation has received little attention (Nash, 2008). Lichen development and abundance are frequently favored by moisture and light requirements, clean air, and undisturbed substratum (Awasthi, 2000). The variable altitude and geography also contribute to the vast lichen variety and endemism. Environmental circumstances, such as humidity, temperature, or precipitation, are examples of elements that impact lichen growth rates (Innes, 1985; Sancho & Hawksworth et al., 2005).

Because of their sensitivity to their surroundings, lichens are recognized as biological monitors of climate conditions. As a result, lichens are sensitive to changes in atmospheric and microclimatic conditions, making them one of the most valuable biological markers for determining environmental stress in tropical and temperate regions (De Silva & Senanayake, 2015; Wolseley & Hudson, 1997). They have three basic growth forms: crustose (cluster-shaped and somewhat flattened in structure), foliose (which has leaf-like structures and is formed of fat tissue), and fruticose (which has leaf-like structures and is comprised of fat tissue) (resembles branching tube-like structures).

Lichens are classified into three types: foliose, fruticose, and crustose. Lichens are abundant and an important food source for herbivores in the particular habitat (Ellis, 2012). Lichens grow in three different ways: crustose, foliose, and fruticose. Crustose has a cluster-shaped structure that is somewhat flattened. Fruticose has the appearance of branching tube-like features. Foliose lichens feature leaf-like lobes and may hybridize with other lichens. Fruticose lichens grow in a "shrubby" manner. Crustose lichens have crust-like bodies that are firmly adhered to their substrates (Beeching & Hill, 2007). The type and quantity of secondary metabolites in lichens are extensively influenced by environmental factors (Brijesh, 2012). The concentrations of melanins and anthraquinones change depending on the quantity of UV-B light present; the mycobiont is thought to be more responsive to such fluctuations than the algal component. The concentrations of usnic and fatty acids decrease as anthropogenic stress levels rise. In contrast, increased salazinic acid levels in lichens in ozone-enriched settings are believed to provide a protective role (Loughran & Berry, 2010).

Lichen compounds also have antioxidant characteristics, which are advantageous at high latitudes where reactive oxygen species occur due to high UV-B levels and lengthy winter darkness (Zuga, 2013). However, the relationship between pigment concentration in thalli, habitat conditions, and lichen growth patterns is complex; for example, the same lichen species can have different physiological responses to UV-B light depending on growing season and habitat conditions, and more research is needed to show how lichens and their secondary metabolites respond to increased UV-B radiation and other aspects of global climate change or local habitat conditions (Grube et al.2009, 2015). The emergence of chemosyndromes in species may be caused by environmental factors such as water availability, sun radiation, and temperature. Ramalina cuspidata's chemical alterations are most likely influenced by an evapotranspiration gradient. In addition, the geographical distribution of another pair of visually similar but chemically different Ramalina species is partitioned. The variability of secondary metabolites within the Cladonia chlorophaea-group chemospecies is also attributable to physiography. Phycosymbiodeme pairs—morphotypes of a species that vary in their photobionts—often include various secondary metabolites, which are also substantially influenced by the environment microclimate (Maciejowski et al., 2018).

The kind of substrate and its qualities are critical for lichens and may outweigh microclimatic considerations. Physical substrate characteristics, surface microtopography, pH, elemental content, and surface availability for colonization are all elements that influence lichen diversity and the organization of saxicolous lichen communities (Sancho & Hawksworth et al., 2005). The great variety of rocks used as a substrate for lichens and related lichen metabolites indicates a large diversity of interactions between them. Lichen acids influence lichens' acidity tolerance and, as a result, their substrate selection (Fazio et al., 2014). On various kinds of rocks, species of the same genus with different metabolites predominate. The chemical elements of lichens' spectrums have been demonstrated to vary from quartzite to limestone. Brun (2011) did so gradually. Metals in the substrate interact with secondary lichen metabolites. Although lichen deterioration of rocks is frequently associated with the secretion of primary metabolites such as oxalic acid, secondary metabolites of lichen have been shown to act as chelating agents, promoting the absorbance of Cu, Fe, Mg, Mn, Ni, and Zn and inactivating potentially toxic elements in thalli. Lichen acids help to thalli's mineral nutrition by promoting metal absorption, which is critical in poor conditions (Paukov et al., 2019).

Lichen is made up of two distinct members from two distinct groups, one of which is a fungal component and the other an algal component. Brijesh's (2012). As a result, it is a dual organism. The algae component is referred to as phycobiont, whereas the fungal component is referred to as mycobiont (Sinha 2015).

Based on their form, the following five categories of thallus organization of lichens are recog¬nized by Hawksworth and Hill (1984). On the other hand, Leprose Lichens, in its simplest form of thallus organization of lichens, the fungal hyphae envelope either one or only a minimal number of algal cells. A distinct fungal layer does not surround the algal cells all over. The simple lichen thallus develops superficially over the substratum, provides a powdery appearance, and is called leprose lichen, e.g., Lepraria incana Kandarp (2013).

Crustose Lichens. These are very adherent to the substrate on which they are present, giving them a crust-like look (Wilkerson, 2016).

Cardinale et al., 2008, 2012) found it difficult to disentangle them from their substratum. Fruiting bodies, such as Graphis Scripta, Lacidia, and Verrucaria, may be found on the top surface. Foliose Lichens, whose thallus is flat, leaf-like, well-branched, and linked to the substratum through rhizines, such as Physcia, Parmelia Peltidea, and others (Weber et al., 2016). Fruticose Lichens. Lichens of this category are well-branched structures, generally erect or sometimes prostrate, and give a shrub-like appearance, e.g., Usnea, Cladonia, Everinea, etc. (De Silva & Senanayake, 2015). Further, Filamentous Lichens, instead of fungal, the algal partner is more developed. Such algal partners are filamentous and remain ensheathed or covered by only a few fungal hyphae. Such lichens are filamentous in appear¬ance, have the dominance of algal partners, and are named filamentous lichens by Hawks-worth and Hill (1984**), e.g., Ephebe, Coenogonium, Cystocoleus, and Racodium.**

Studies on Lichen Diversity and Distribution

To understand the functions of lichens, the distribution of lichen species and the factors influencing their distribution must be determined. Saljo's (2016). The host tree species (tree height, age, diameter, branch density, pH of tree bark, bark structure, and water holding capacity of bark), the position of trees in the stand (canopy closure, species mixture, number of trees per ha), and the site quality (aspect, slope, and altitude) all influence lichen diversity (Backlund et al., 2016). The water and nutrient budgets of a specific location are influenced by topographical factors (Loughran & Berry, 2010). Many topographical characteristics have been included into models to explain the distribution of plant species and plant society (Engelhardt et al., 2012).

Some restricted topographical factors are employed to determine the impacts on lichen species diversity, such height, exposure, and slope. In studies attempting to understand the relationship between lichen species diversity and topographical variables, the northness, general curvature, catchment slope, and slope length have rarely been included (Ardelean et al., 2015). The diversity of lichen species in Mediterranean woodlands fluctuates as a result of tree type (Nascimbene et al., 2013). The distribution of lichen species in Mediterranean plant species has been researched (Christensen, 2014).

Furthermore, lichens may grow from low-tide levels to mountain heights, as well as in arctic, desert, and tropical temperature zones (Abas et al. 2018). Lichens are unusual dual-organisms (fungus as mycobiont and bluegreen algae or cyanobacteria as photobiont) that can respond quickly to environmental changes (Abas et al. 2020). Some species can thrive under extreme environmental circumstances, while others are wiped off by even little alterations. Lichens develop in three distinct ways: crustose (attached to the substratum), foliose (leaf-like and loosely connected to the substratum), and fruticose (bush-like and either hangs or grows erect on the substratum) (Gaurav & Upreti 2016). Lichens and their metabolites have a wide range of biological properties, including antimicrobial, antiprotozoal, antiviral, anti-proliferative, anti-inflammatory, analgesic, antipyretic, anti-termite, antioxidant, cytotoxic, enzyme inhibitory, insecticidal, wound healing, and antitumor properties (Kosani et al. 2013; Rajan et al. 2016).

Synthesis

Most lichens are xerophytes (adapted to dry conditions) and can be found on rocks and soil in dry and warm regions. Some lichens are aquatic or mesophytes (adapted to moderate moisture), while others thrive in deep shaded woods, cool cliffs, and damp soil. Peltigera species are representative of mesophytic forms. Lichens are symbiotic associations between fungi and green algae or cyanobacteria. The fungi provide habitat and retain water and minerals, while the photosynthetic partners receive nutrients. There are approximately 20,000 species of lichens worldwide, with 14,000 named species. In the Philippines, there are 1,108 taxa distributed in 137 genera, 786 species, and 253 varieties.

Lichens are sensitive to environmental changes, making them useful indicators of air quality, pollution, and climate change. Some lichen species have medicinal uses and act as keystone species in forest ecosystems, influencing mineral cycling, microclimate, and providing food and shelter for insects. Lichen diversity is influenced by moraine age and climatic and anthropogenic gradients. Lichens consist of fungal filaments surrounding photosynthetic cells. The thallus is the vegetative tissue of a lichen and may have a cortex (protective skin), medulla (less densely packed fungal filaments), and lower cortex (in foliose lichens). Different growth forms include fruticose (branching), foliose (leaf-like lobes), crustose (crust-like), and squamulose (marginally lifted). Reproductive structures and pigments contribute to the visual characteristics of lichens.

Phenotypic traits such as thallus morphology, architecture, reproductive structures, and chemistry are important for distinguishing lichen species. Sexual and vegetative propagules play a role in species dispersal and colonization. Lichens can display vibrant colors, especially when moist, covering rock surfaces or hanging from tree bark. The color of a lichen can vary depending on moisture levels, and identification is often based on the color when dry.

Moreover, lichens are ecologically important organisms with diverse adaptations and structural characteristics. They play a role in environmental monitoring, ecosystem functioning, and can provide aesthetically pleasing displays in natural settings.

METHODOLOGY

This part presents the methods and procedures used in the conduct of the study. These included the research design, research locale, and research respondents. The research was conducted in New Leyte, Maco, Davao De Oro, Philippines.

Research Design

The researcher used descriptive research and ecological research design in this study. As Clause (2013) emphasized, descriptive research is a process of collecting data on a specific variable as it occurs in the environment and answering questions concerning the status of the study. Furthermore, descriptive research describes the characteristics of a population or phenomenon being studied, and the researcher has no control over variables. This study used descriptive research to gather data regarding lichen species' taxonomy, biodiversity, and ecological status.

On the other hand, the ecological research design is a design where ecologists rely primarily on observation and fieldwork. This entails going into the habitat of the subject of interest to observe it in its natural state (Dotson, 2019). By doing field surveys, ecologists can track species' population growth, observe community ecology in action, and study the impact of any new species or other introduced phenomena in the environment. Furthermore, this technique included establishing goals and developing a sampling strategy, sampling in the field, sorting, identifying, and labeling the species obtained, and data analysis. The findings may be used to calculate absolute or relative population sizes, create life tables, investigate population dynamics, and quantify biodiversity (Henderson, 2002).

Data Analysis

Data Collection of Ecological Parameters. The ecological parameters determined during the sampling period within the study area are the following.

Substrate. The substrate was determined through visual observation and was recorded for each quadrat based on the categories: bark, branches, twig, rocks, soil, etc.

Elevation distribution. An altimeter is an instrument to measure the altitude of the study area. The elevation where some of the specimens were collected was noted through the use of the altimeter.

Lichen Distribution. The biological stands of tropical forests alter every 200–400 m, according to Zulkifly et al. (2011). In this study, to determine the diversity and distribution of the lichens at different elevations, 300 m interval was used to determine the different collection sites: Site 1 has an elevation range from 750 m – 1049 m; Site 2, 1050 m – 1349 m; Site 3, 1350 m – 1649 m; Site 4, 1650 – 1949 m; and, Site 5, 1949 – 2250 m.

Taxonomy of lichen flora. All lichens present inside the quadrats were identified, recorded, and classified. There was also the construction of taxonomic keys based on the identified, recorded, and classified lichen.

Identification procedure of the lichen species. The researcher pre-identified the specimen in Mt. Canadalaga through iNaturalist, an application and taxonomic keys in the Asian countries used to identify the organism. iNaturalist application helps people, in general, identify plants and animals and the taxonomic keys for lichen species. It consists of suggestions from scientists and naturalists worldwide and only needs to import photos captured to run the app and give suggestions as to what organism it could be. The researcher used the app to pre-identify what kind of lichen species. The researcher brought the gathered lichens personally to a lichenologist in Baguio City to confirm and verify their identification and hands-on learning on the procedures on how to identify the lichens.

Collection and Preparation of Herbarium Specimens. A guide from Shevock et al. (2014) was utilized to collect lichen species and prepare for herbarium specimens. The ideal collection method for the lichens is to place a sample directly into a small folded paper packet.

Photographs and Documentation of Lichen Species. Photographs were captured from actual observations in the field to record their natural color, while photographs from the microscopic examination were taken to characterize and identify species' morphology. Digital Single Lens Reflex (DSLR) and iPhone 11 ProMax were used to capture the lichen species' photos.

RESULTS AND DISCUSSION

A total of thirty-three (33) species were collected in the montane forest of Lake Leonard, New Leyte, Maco, Davao de Oro, Province through transect walk sampling. Results revealed a total of thirty-three (33) species with nineteen (19) genera and twelve (12) families.

Table 1. List of Lichen Family and Number of Genus and Species

	Family	Genera	Species
1	Pertusariaceae	1	9
2	Physciaceae	3	7
3	Parmaliaceae	4	6
4	Collenmataceae	2	2
5	Graphidaeceae	2	2
6	Cladoniaceae	1	1
7	Coccocatpiaceae	1	1
8	Teloschistaceae	1	1
9	Ramalinaceae	1	1
10	Hygrophoraceae	1	1
11	Thelotremataceae	1	1
12	Sterocaulaceae	1	1
Total	**12**	**19**	**33**

Table 1 presents the list of Lichen Family and number of genus and species. The different families noted in their order are: Family Pertusariaceae with 9 species which belonging to 1 genera. Physciaceae with 7 species and 3 genera. Parmaliaceae with 6 species and 4 genera. Collenmataceae with 2 species and 2 genera. Graphidaeceae with 2 species and 2 genera. Cladoniaceae with 1 species belonging to 1 genera. Coccocatpiaceae with 1 genera and 1 species. Teloschistaceae with 1 species and 1 genera. Ramelinaceae with 1 species and 1 genera. Hygrophoraceae with 1 species and 1 genera. Thelotremataceae with 1 species and 1 genera. Sterocaulaceae with 1 species and 1 genera. A total of twelve (12) families collected in the study area with nineteen (19) genera and thirty-three (33) species. The Family Pertusariaceae obtained the most numbered species and Parmaliaceae obtained the most numbered.

According to the Sancho & Hawksworth et al. (2005) research, the substrate type and its features are crucial for lichens and may outweigh microclimatic influences. Physical substrate characteristics, surface microtopography, pH, elemental content, and surface availability for colonization are all elements that influence lichen diversity and the organization of saxicolous lichen communities. Furthermore, Fazio et al. (2014) said that the great variety of rocks used as a substrate for lichens and related lichen metabolites imply many interactions between them. Lichen acids influence lichens' acidity tolerance and, as a result, their substrate selection.

Table 2. Ecological Status of the Collected Lichen Based on Local Assessment

FAMILY NAME	GENERA	SPECIES	ELEVATION (m asl)	No. of Species	ECOLOGICAL STATUS
Pertusariaceae	*Pertusaria*	sp.1	857	1	Rare
	Pertusaria	sp.2	841.17	1	Rare
	Pertusaria	*velata*	857	1	Rare
	Pertusaria	*albescens*	832.13	1	Rare
	Pertusaria	*globularis*	832.13	1	Rare
	Pertusaria	sp.3	832.13	1	Rare
	Pertusaria	*hemisphaerica*	857	1	Rare
	Pertusaria	*amara*	857	1	Rare
	Pertusaria	*multipuncta*	857	1	Rare
Physciaceae	*Pyxine*	*philippina*	841.17	1	Widespread
	Physcidia	*cylindrophora*	841.17	1	Rare
	Pyxine	*bertariana*	862.48	1	Rare
	Physcia	*tribacioides*	862.48	1	Rare
	Physcia	*stellaris*	841.17	1	Rare
	Pyxine	*consocians*	832.56	1	Rare
	Physcia	*aipolia*	841.17	1	Rare
Parmaliaceae	*Usnea*	*cornuta*	887.19	1	Rare
	Parmotrema	*gardneri*	854.63	1	Widespread
	Parmotrema	*tinctorum*	854.63	3	Widespread
	Hypogymnia	*physodes*	854.63	1	Rare
	Flavoparmelia	*caperata*	887.19	1	Rare
	Parmotrema	*perlatum*	887.19	1	Rare
Collenmataceae	*Collema*	sp.	863.27	1	Rare
	Leptogium	*furfuraceum*	856.43	1	Rare
Graphidaeceae	*Graphis*	*analoga*	856.43	1	Rare
	Platygramme	sp.	863.27	1	Rare
Cladoniaceae	*Cladonia*	*cornuta*	863.27	1	Rare
Coccocatpiaceae	*Coccocarpia*	*adnate*	889.27	1	Rare
Teloschistaceae	*Caloplaca*	sp.	889.27	1	Rare
Ramalinaceae	*Bacidia*	sp.	889.27	1	Rare
Hygrophoraceae	*Dictyonema*	*sericeum*	889.27	1	Rare
Thelotremataceae	*Ocellularia*	*granulosa*	852.34	1	Rare
Sterocaulaceae	*Stereocaulon*	*ramulosum*	852.34	1	Rare

Table 2 shows the Ecological Status of the collected lichen based on local assessment Most of the collected species were rare. Only few were found widespread in the study site. These belongs to: *Parmotrema gardneri,* with 1 species found at an elevation of 854.63 meters above sea level; *Parmotrema* *tinctorum* with 3 species found at an elevation of 854.63 meters above sea level; and *Pyxine philippina* with 1 species found at an elevation of 841.17 masl.

Furthermore, this is consistent with the results of Boonpeng et al. (2017), who discovered that research conducted in tropical forests have indicated that climatic parameters (e. g., temperature and humidity) and forest structure change dramatically with altitude. Furthermore, Sulaiman et al. (2018) stated that lichen diversity, composition, and distribution are highly related to, and impacted by, environmental conditions and forest structure.

Synthesis

This result can be linked to studies conducted by Nascimbene et al. (2013) and Christensen (2014). Their results revealed how lichen species diversity varies as a result of tree species in Mediterranean forests, and how lichen species dispersion has been researched in Mediterranean plant species. Furthermore, Negi and Upreti (2000) determined that lichens thrive in a variety of ecological situations, ranging from arctic settings to tropical rainforests, and that they colonize a broad range of substrates, including rock, bark, soil, and even leaf/bark surfaces.

CONCLUSION AND RECOMMENDATION

Based on the findings of the study, the following conclusions are drawn:

1. The inventory of lichen species revealed thirty-three (33) species which belong to nineteen (19) genera and twelve (12) families namely: Pertusariaceae, Physciaceae, Parmaliaceae, Collenmataceae, Graphidaeceae, Cladoniaceae, Coccocatpiaceae, Teloschistaceae, Ramalinaceae, Hygrophoraceae, Thelotremataceae and Sterocaulaceae. The (19) genera includes: Pertusaria, Pyxine, Physcidia, Physcia, Usnea, Parmotrema, Hypogymnia, Flavoparmelia, Collema, Leptogium, Graphis, Platygramme, Cladonia, Coccocarpia, Caloplaca, Bacidia, Dictyonema, Ocellularia, Stereocaulon.
2. The species were classified, identified, and described according to their ecological and physical characteristics such as: growth form, color, presence of reproductive structure and habitat.
3. The species collected in the study area, Pertusariaceae family is the most species-rich family with 9 identified species.
4. Most of the collected species in the study area were rare. Only few were found widespread in the study site. These belongs to: Parmotrema gardneri, with 1 species found at an elevation of 854.63 meters above sea level; Parmotrema tinctorum with 3 species found at an elevation of 854.63 meters above sea level; and Pyxine philippina with 1 species found at an elevation of 841.17 masl.

Based on the findings and conclusions of the study, the following recommendations are given:

1. Based on the findings, the following recommendations are hereby given:
2. More explorations and collections may be done to identify additional

lichen species at Lake Leonard, New Leyte, Maco, Davao de Oro Province.

3. Similar investigations may be studied in monitoring the lichen species as bioindicator of pollution in other parts of the study area.
4. Lichens collected may be identified by experts to obtain correct identifications and classification.
5. Future researchers may conduct further study and establishment of more sampling plot.
6. Anatomical structures may be studied to find out active components and medicinal properties.

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