



## **Occurrence and diversity of myxomycetes along the forest edges of Mt. Isarog National Park, Camarines Sur, Philippines**

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### **Abstract**

Forest edges support a unique biodiversity distinct from the inner part of the forest. While species diversity of plants and animals were widely reported along forest edges, little is known about its microbiota, particularly myxomycetes. In this study, we evaluated the occurrence and diversity of myxomycetes found along forest edges in Mt. Isarog National Park in the Bicol Region, Philippines. Ground leaf litter (GL) and decaying twigs (TW) were collected from three sampling localities and used for the setting up of moist chambers. Here, a total of 540 moist chamber cultures were prepared. From these, we recorded 24 identifiable species belonging to 10 genera, namely, *Arcyria*, *Comatricha*, *Cribraria*, *Diachea*, *Diderma*, *Didymium*, *Hemitrichia*, *Perichaena*, *Physarum*, and *Stemonitis*. Of these, 11 species were shared by all sampling localities. We observed differences in myxomycete composition between the three forest edges.

**Keywords** – forest edge – forest fragmentation – slime molds – species list – tropical forests

### **Introduction**

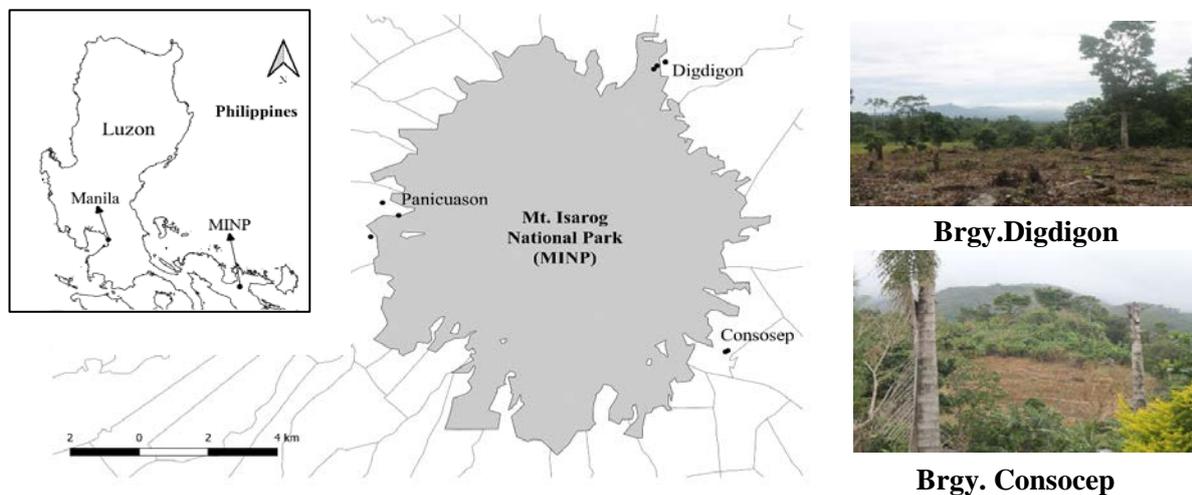
Forest edge is described as the interface between the forested and non-forested ecosystems or between two forests of contrasting composition or structure (Harper et al. 2005). This is a result of the conversion of pristine forest lands into agricultural and/or urban areas. Forest edges contribute to worldwide declines in biodiversity and ecosystem functions. In the meta-analysis conducted by Pfeifer et al. (2017), the abundance of 1,673 species of mammals, birds, reptiles, and amphibians in forests around the globe were affected by forest fragmentation. Pfeifer and colleagues further noted that forest edges altered the abundance of 85% of these species, expressed as a strong decline in species abundance towards forest edges. Forest edges has also profound influences on plant species composition, and on microclimate and ecosystem processes (Zheng et al. 2005). Interestingly, though forest edges had generally negative impacts on plants and animals, several studies identified these areas as hotspots of biodiversity for other species, e.g. insects. Müller et al. (2007) in their flight interception trap study of 12 different forest edges in the Bavarian Forest National Park in Southeastern Germany determined 10,966 specimens representing 421 insect species categorized as 240 beetles, 96 true bugs, 65 Aculeata, and 20 lacewings. The highest number of species was found in the open spaces in these forest edges. In another study, Duelli et al. (2002) compared the arthropod

biodiversity in five differently structured forest edges and in areas 50 m inside the forest. They reported fewer species inside the forest than the forest edges. Their study also showed that the steep forest edges contained 24% more species of arthropods than the forest interior. If insect diversity were shown to be high along forest edges, would myxomycete diversity also be high given that myxomycetes were reported to feed upon by insects such as beetles and ants, and therefore are easily dispersed by insects? This led us to ask further this question: Do the species of myxomycetes differ along forest edges in Mt. Isarog? We hypothesized that the assemblages of myxomycetes would be similar in composition along the forest edges in a tropical lowland forest, here represented by Mt. Isarog National Park in Camarines Sur, Philippines.

## Materials & Methods

### General study area

Mt. Isarog is a potentially active stratovolcano bordered by the municipalities of Naga, Pili, Ocampo, Tigaon, Goa, Tinambac, and Calabanga in the province of Camarines Sur, Luzon Island, Philippines. Designated as Mt. Isarog National Park (MINP), it has a total land area of 10,112 hectares (has) and a peak that rises to 1,966 meters above sea level (masl), making it the most dominant physical and natural landmark in the province of Camarines Sur. It has an average annual temperature of 27.1°C, an average rainfall of approximately 2,214.3 mm, and a relative humidity of about 85%. There are four distinct forest types in Mt. Isarog, namely, dwarf forest, mossy forest, montane upper rainforest, and the lowland forest. Dominant tree species belong to the dipterocarp family, e.g. *Shorea polysperma* (Blanco) Merr.. Grassland is also present, particularly at the foot of the mountain or where human settlements are present and is dominated by *Saccharum spontaneum* L., commonly known as “talahib” and *Imperata cylindrica* (L.) P. Beauv. or “cogon”. Agricultural plantations are frequent near the forested areas. In the past and until present, Mt. Isarog has been heavily disturbed by human activities, e.g. deforestation, agriculture use, etc (Verburg et al. 2006, Sedlock et al. 2008).



**Fig. 1** – Map of Mt. Isarog National Park, with the sampling points marked by black dots (map modified and generated using QGIS 3.12). Photos were taken by MFBM Eloreta.

In this study, three sampling localities along forest edges were chosen, each with nine collecting points (Fig. 1). The three sampling localities were described as follows: (A) Brgy. Digdigon (DG, 13°43'14.52"N, 123°25'2.64"E) located in the municipality of Goa, Camarines Sur had a vegetation area of approximately 325.88 has and an elevation of 258.9 masl, (B) Bgy. Consocep (CS, 13°37'55.2" N, 123°24'55.08"E) located in the municipality of Tigaon, Camarines Sur has a vegetation area of 269.44 ha and an elevation of 742.3 masl, and (C) Brgy. Panicuason (PN,

13°39'36" N, 123°19'46.92" E) located in the city of Naga, Camarines Sur has a vegetation area of 661.74 ha and an elevation of 428.2 masl. All sampling localities have Climate Type II, i.e., no clear dry period but with a very distinct rainy season from the months of December to February. Within these three sampling localities, nine collecting points of 10x10 m<sup>2</sup> quadrats were chosen for the collection of substrates in November 2018. GPS of each collecting points were determined using the Department of Agriculture (DA) Geotagging app.

### **Collection of substrates and setting up moist chambers**

Ten samples were collected for each of ground leaf litter (GL) and twigs (TW) per collecting point, resulting in 90 samples per substrate type or 180 samples per sampling locality. The substrates were placed inside dry paper bags, properly labeled per sampling site, air dried for 4-5 days and then, transported to the Mycology Laboratory, University of Santo Tomas in Manila, Philippines for moist chamber preparation. Collection of substrates commenced following the issuance of gratuitous permit from the Department of Environment & Natural Resources Regional Office V through its Protected Area & Management Bureau Office in Camarines Sur.

To set up the moist chambers, leaf litter were incised into postage stamp-size pieces and placed inside 90-mm diameter petri dishes lined with tissue paper. Dried twigs were cut approximately 5 cm in length and were placed inside moist chamber plates. All petri plates were flooded with distilled water and soaked overnight at room temperature. After soaking the substrates with distilled water, the pH was measured using pH meter and excess water was poured out. All moist chambers were incubated at room temperature (22-25°C) under diffuse light and were examined every week for the growth of plasmodia and fruiting bodies under a dissecting microscope (Olympus SZ61-ILST). Observation period lasted for 8-12 weeks with a small amount of water added from time to time, to maintain the moisture of the moist chamber plates. Substrates with identifiable fruiting bodies of myxomycetes were transferred and glued to herbarium boxes as voucher specimen with informative labels which includes the specimen number, collection site, date of collection, name of collector, substrate, identity of the species, and other pertinent information. Collected specimens were deposited at the Myxomycete Collection of the Mycology Laboratory, University of Santo Tomas, Manila.

### **Identification and ecological analysis**

Identifiable fruiting bodies derived from the moist chamber cultures were observed under a dissecting microscope for the following characters: type, size, shape, and color of fruiting bodies, appearance of stalk, and presence of lime. Microscopic characterization was also conducted on a glass slide to describe internal structures such as spore, capillitium, and columella. Slides were observed under a compound microscope (Olympus CX21) at 400× to 1,000× magnification. Identification of the species was done by comparing morphometric data with published literature.

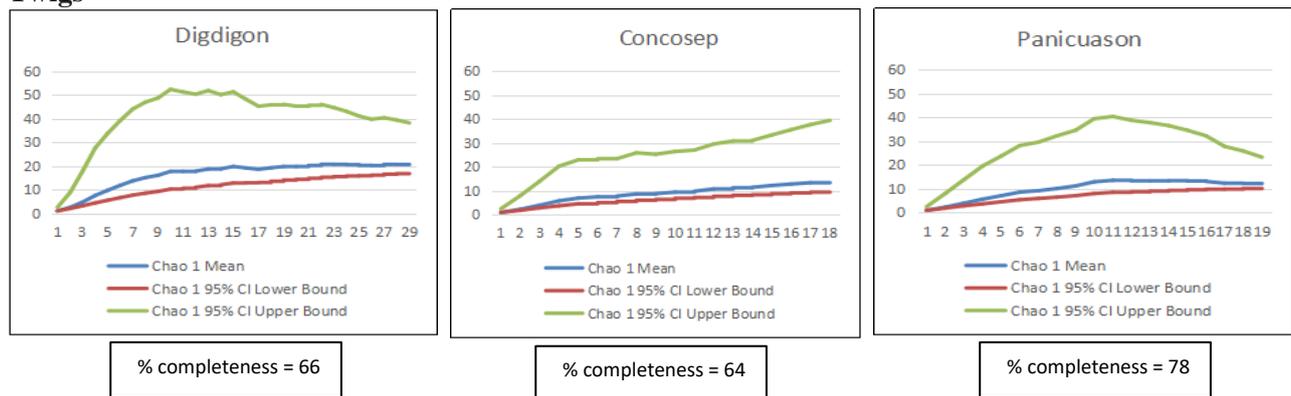
Moist chamber (MC) with growth of either plasmodium or fruiting body of myxomycetes were regarded as one positive record. The moist chamber productivity was determined as the number of positive collections divided by the total number of MCs prepared (Macabago et al. 2012). Species occurrence for each of the substrate types and sampling locality was determined based on the absence and presence of a particular species of myxomycetes in the moist chambers. Relative abundance and the corresponding Abundance Index (AI) were also determined by dividing the total number of each species by the total number of myxomycetes collected multiplied by 100 (Stephenson et al. 1993). The abundance data was also used to compute the species diversity, i.e., Fisher's  $\alpha$ , Simpson and Shannon indexes, using the software Estimate S (Version 9.1) and to construct species accumulation curve (SAC). The taxonomic diversity index (TDI) was calculated as the ratio of the number of species against the number of genera (S/G ratio). A Venn diagram was also generated for community analysis to show the distribution of species between the three localities. Similarity indices were computed, i.e. Sorensen's Coefficient of Community (CC) which considers the presence or absence of a species in three localities being compared and Percentage of Similarity (PS) index which accounted for both presence and absence of a species and its relative abundance. The CC values range

from 0 (no species common in the localities being compared) to 1 (all species are present in the localities being compared). Similarly, the PS values range from 0 to 1 with the value closer to 1 indicating that the localities being compared are highly similar in terms of species composition and abundance.

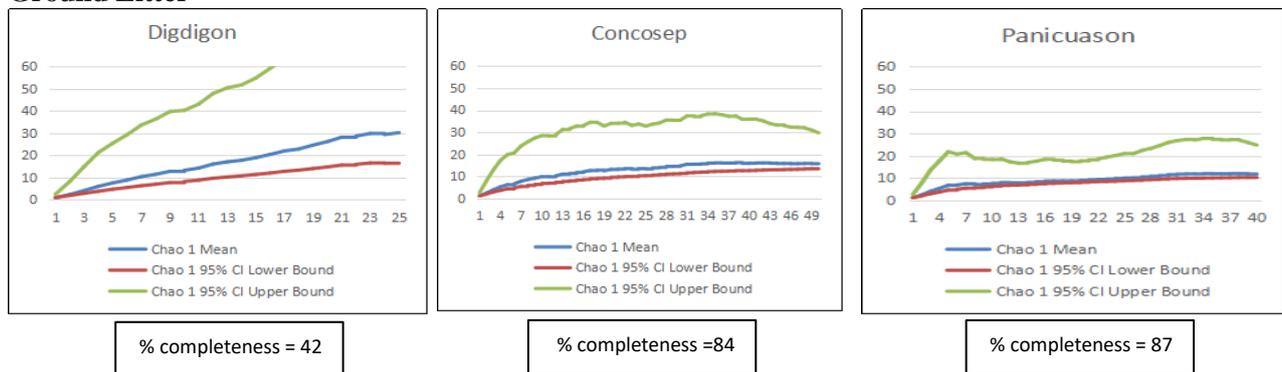
## Results

Of the 540 MCs prepared in this study, 324 yielded positive growth of myxomycetes either as plasmodium or sclerotia (94) and fruiting bodies (230) that resulted in a moist chamber productivity of 60%. To assess the completeness of the sampling strategy for each of the sampling localities per substrate type, a species accumulation curve (SAC) was constructed for both GL and TW (Fig. 2). The computed values ranged from 42% to 87% completeness.

### Twigs



### Ground Litter



**Fig. 2** – Species accumulation curves (SAC) for the three localities (Digidigon, Concosep & Panicuason) per substrate type (twigs, ground leaf litter).

A total of 24 species of myxomycetes were identified in the three forest edges (Table 1). These belonged to Trichiales (7 taxa), Physarales (12 taxa), Stemonitales (4 taxa), and Cribrariales (1 taxon). Of these, three taxa were abundant, three were recorded as common, and six were occasionally occurring. Twelve species were considered as rare. The abundant species were *Arcyria cinerea*, *Diderma effusum*, and *Physarum globuliferum*.

**Table 1** Occurrence of myxomycetes along three forest edges in Mt. Isarog National Park, Camarines Sur, Philippines.

Taxa	Frequency Pooled	AI	Locality			Substrate	
			DG	CS	PN	TW	GL
<b>Trichiales</b>							
<i>Arcyria cinerea</i> (Bull.) Pers.	26	A	3	12	11	13	13
<i>Arcyria denudata</i> (L.) Wettst.	15	C	6	7	2	5	10

**Table 1** Continued.

Taxa	Frequency Pooled	AI	Locality			Substrate	
			DG	CS	PN	TW	GL
<i>Hermitrichia calyculata</i> (Speg.) M.L. Farr	3	R	2	0	1	2	1
<i>Hermitrichia serpula</i> (Scop.) Rostaf.	3	R	1	1	1	1	2
<i>Perichaena chrysosperma</i> (Currey) Lister	5	O	5	0	0	5	0
<i>Perichaena depressa</i> Libert	5	O	0	4	1	3	2
<i>Perichaena pedata</i> (Lister & G. Lister) G. Lister	7	O	2	4	1	4	3
<b>Physarales</b>							
<i>Diachea leucopodia</i> (Bull) Rostaf.	9	O	1	8	0	0	9
<i>Diderma effusum</i> (Schwein.) Morgan	20	A	9	1	10	2	18
<i>Diderma hemisphaericum</i> (Bull.) Hornem	12	C	1	5	6	2	10
<i>Didynium bahiense</i> Gottsb	4	R	1	1	2	0	4
<i>Didynium nigripes</i> (Link) Fr.	8	O	2	3	3	5	3
<i>Didynium squamulosum</i> (Alb. & Schwein.) Fr.	15	C	6	3	6	3	12
<i>Physarum</i> sp.	1	R	1	0	0	1	0
<i>Physarum compressum</i> Alb. & Schwein.	2	R	2	0	0	1	1
<i>Physarum decipiens</i> M.A. Curtis	2	R	2	0	0	1	1
<i>Physarum globuliferum</i> (Bull.) Pers	25	A	1	17	7	2	23
<i>Physarum melleum</i> (Berk. & Broome) Massee	1	R	1	0	0	1	0
<i>Physarum oblatum</i> T. Macbr	4	R	1	3	0	4	0
<b>Cribrariales</b>							
<i>Cribraria microcarpa</i> (Schrad) Pers.							
<b>Stemonistales</b>							
<i>Comatricha nigra</i> (Pers ex J. F Gmel) J. Schrot	2	R	1	0	1	1	1
<i>Comatricha pulchella</i> (C.Bab. & Berk.) Rostaf.	3	R	2	1	0	3	0
<i>Stemonitis pallida</i> Wingate	2	R	0	0	2	1	1
<i>Stemonitis smithii</i> T. Macbr	6	O	1	3	2	6	0

<sup>a</sup> locality: Digdigon (DG), Concosep (CS), Panicuason (PN)

<sup>b</sup> substrata: ground leaf litter (GL), twigs (TW)

<sup>c</sup> Abundance Index (AI) by Stephenson et al. (1993)

R = rare, if the number of specimens (abundance) of a particular species is <0.5% of the total number of collections

O = occasional, if the abundance is ≥0.5% but <1.5%

C = common, if the abundance is ≥1.5% but <3%

A = abundant, if the abundance is ≥3%

Comparing the diversity indices between the three localities and the two substrate types, DG had the highest diversity as compared to PN and CS, although the TDI was low in CS, hence was more taxonomically diverse, where 17 taxa belonging to 10 genera were recorded (Table 2). For substrate type, TW had greater diversity than GL. TW in DG had the highest diversity when both the substrate type and locality were considered.

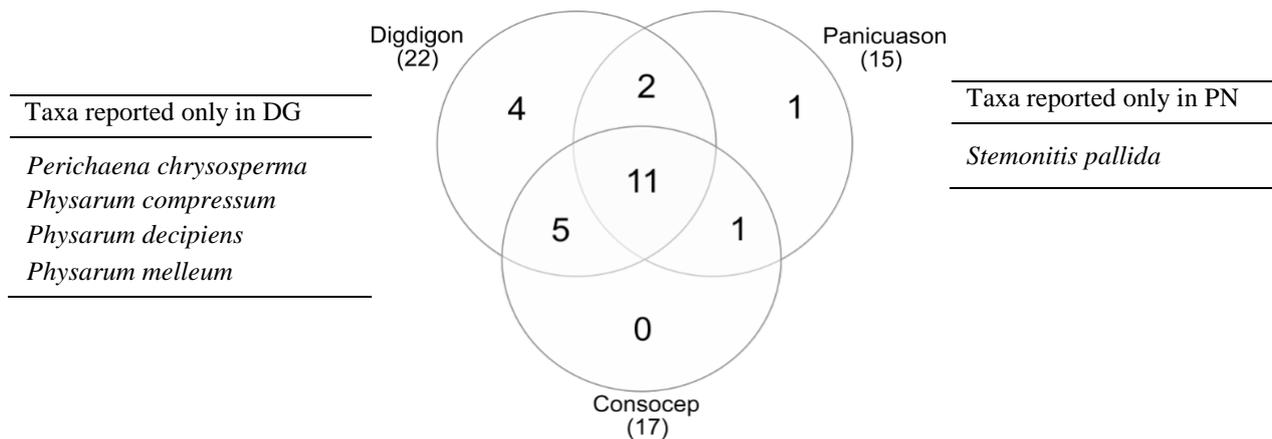
**Table 2** Taxonomic and species diversity of myxomycetes recorded per locality and substrates.

	Total No. of records	No. of species	No. of genera	TDI	Shannon Index	Simpson Index	Fisher Alpha
<b>Locality</b>							
DG	52	22	10	2.2	2.78	12.18	14.39
CS	76	17	10	1.7	2.46	8.91	6.80
PN	56	15	8	1.9	2.36	8.43	6.71
<b>Substrates</b>							
Tw	67	21	8	2.6	2.77	12.3	10.51
GL	117	19	10	1.9	2.46	9.13	6.43
<b>Substrate per Locality</b>							
DG	Tw	27	15	8	1.9	2.50	10.56
	GL	25	13	8	1.6	2.26	7.18

**Table 2** Continued.

		Total No. of records	No. of species	No. of genera	TDI	Shannon Index	Simpson Index	Fisher Alpha
CS	Tw	21	10	7	1.4	2.12	7.23	7.48
	GL	55	13	8	1.6	2.12	6.19	5.37
PN	Tw	19	10	7	1.4	2.09	6.33	8.54
	GL	37	9	6	1.5	1.94	5.98	3.79

<sup>a</sup> locality: Digdigon (DG), Consocep (CS), Panicuason (PN); substrata: ground leaf litter (GL), twigs (TW)



**Fig. 3** – Venn diagram showing the distribution of the 24 myxomycetes species in the three sampling localities and indicating the number of shared species between the forest edges. The total number of taxa recorded for each sampling locality is presented in parenthesis.

Looking at the species composition of the forest edges, there were 11 species present in all localities, namely *Arcyria cinerea*, *Arcyria denudata*, *Comatricha nigra*, *Diderma effusum*, *Diderma hemisphaericum*, *Didynium bahiense*, *Didynium nigripes*, *Didynium squamulosum*, *Hermitrichia calyculata*, *Physarum globuliferum*, and *Stemonitis smithii*. However, only few taxa, between 1 to 5, were shared by any two of the localities. There were four species, namely, *Perichaena chrysosperma*, *Physarum compressum*, *Physarum decipiens*, and *Physarum melleum* that were unique for DG, meaning it was not recorded in the other localities (Fig. 3). One species, *Stemonitis pallida*, was recorded in PN. This study also recorded 15 species shared by the two substrata (data not shown). When comparing their similarity indices between the three localities, our results showed the highest CC values was between DG and CS (0.82), but the highest PS values was between DG/PN and CS/PN (0.56-0.57).

**Table 3** Sorensen’s Coefficient of Community (lower left) and Percent Similarity (upper right) values of the three sampling localities.

		PS Values		
Locality		DG	CS	PN
CC values	DG		0.44	0.56
	CS	0.82		0.57
	PN	0.65	0.75	

## Discussion

A diverse species composition of plants and animals were widely reported along forest edges. For example, forest edges showed a high species diversity of insects (Müller et al. 2007). In the study of Dillon et al. (2018), the three invasive tree species, *Elaeagnus umbellata*, *Ligustrum obtusifolium*,

and *Lonicera maackii*, had also greater abundance at forest edges than the forest interiors. Duelli et al. (2002) in a two-year collecting study identified 58 species of Neuroptera along forest edges. While forest edges appeared to support insect diversity and invasive tree species, no studies have so far look at its impact to microbial flora such as myxomycetes.

In this study, a total of 184 records consisting of 24 species and 10 genera of myxomycetes were identified from moist chamber cultures (Tables 1-2). A survey of myxomycetes in lowland forest habitats in the Philippines were previously conducted where the recorded number of species vary, e.g. in Mt. Arayat, 33 taxa by Dagamac et al. (2011) in Lubang Island, 45 taxa (Macabago et al. 2012), in Polillo Island, 34 taxa (Viray et al. 2014), in Quezon National Park, 35 taxa (Dagamac et al. 2015) and in Puerto Princessa Subterranean River National Park, 33 taxa (Pecundo et al. 2017). Between the three localities, DG had 22 species, and thus, also showed the highest species diversity, i.e., Shannon index = 2.78, Simpson index = 12.18, FAI = 14.39 (Table 2). Higher diversity was also recorded for DG regardless of the substrate type. Interestingly, among the three localities, DG had the lowest elevation. The area is also near agricultural plantations where man-made activities are also frequent. It would therefore be interesting to study how man-made activities or movement influence the dispersal and distribution of myxomycetes. Between substrata, twigs (21) had higher species number than ground leaf litter (19), hence, had also a higher species diversity (Table 2). This pattern was also observed regardless of sampling locality. In the study of Dagamac et al. (2017) in the Bicol Peninsula where Mt. Isarog was also listed as one of the study sites, they listed 32 species, albeit upon re-checking only 29 taxa, belonging to 14 genera from moist chambers in contrast to the 24 species and 10 genera recorded here. Dagamac and his colleagues recorded their 29 taxa from field collection and from 90 MCs of aerial litter, ground litter, and twigs collected from lowland forest characterized of having either old growth forest or successional forest patches where there is more heterogeneity of plant communities, slightly disturbed, and along a steep trail covered with large trees. Though a higher number of MC was used in this study, a total of 540 as opposed to 90, differences in species number and even composition was observed. For example, 11 species were recorded in both studies while 12 species reported herewith, excluding *Physarum* sp., were not found in the study of Dagamac et al. (2017). This brings the total number of species reported in Mt. Isarog National Park to 41.

Of the species collected in this study, three were reported as abundant (Table 1). The abundant taxa, *Arcyria cinerea*, *Diderma effusum*, and *Physarum globuliferum*, were also reported in other areas as abundant, e.g. in Mt. Arayat National Park (Dagamac et al. 2014), and in Lubang Island (Macabago et al. 2016). There were species reported as rare in other similar studies, e.g. *Didymium squamulosum* and *Perichaena depressa* (Dagamac et al. 2012, Rea-Maminta et al. 2015) but were common here. In the study of Rojas & Stephenson (2007), *Didymium squamulosum* was recorded as abundant while *Perichaena depressa* was rare. Evidently, according to Bernardo et al. (2018), rare species can either stay in a community where life is steadier but no chances of invasion due to higher competition, or transfer to another community where chances of survival are lower as well as competition and thus, invasion is more achievable.

Comparing the composition for the three localities, a Venn diagram illustrated a high number of shared species (11) between the three sampling localities (Fig. 3). The highest CC values and PS values were also observed between DG and CS (0.82) and between CS and PN (0.57), respectively. In addition, DG and CS has the highest number of shared species (5), followed by DG and PN (2), and lastly, PN and CS (1 species only). Interestingly, DG harbored the greatest number of unique species among the three localities, with 4 recorded taxa.

In summary, the present study reported species of myxomycetes along the forest edges of Mt. Isarog National Park. MINP is already considered as a vulnerable habitat due to a number of habitat alteration, e.g. deforestation, tourism activities, agriculture use, linked with human settlers in the area. It has been known that these anthropogenic disturbances may contribute to fragmentation and the occurrence of forest edges along its forest structures. While studies on the impact of forest disturbance are reported for plants and animals, very few studies looked at how habitat disturbance affect microorganisms. In the study by Bernardo et al. (2018), they reported differences in disturbance

gradient between a primary undisturbed forest and an extremely disturbed forest in Laguna, Philippines, particularly in the two municipalities in Laguna - Los Baños and Calauan. Their results revealed a higher species diversity in Los Baños than in Calauan. Their study showed that the diversities of myxomycete communities were lower in undisturbed forest and in an extremely disturbed forest than in moderately disturbed forest fragments. Our study contributes to the continuous understanding of the impacts of habitat disturbance brought about by anthropogenic activities to the communities of myxomycetes.

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### **References**

- Bernardo J, Arioder L, Almadrones-Reyes K, Dagamac N. 2018 – Myxomycete communities occurring in fragmented forest patches in two municipalities of Laguna, Philippines. *Community Ecology* 19, 289–299.
- Dagamac NHA, dela Cruz TEE, Pangilinan MVB, Stephenson SL. 2011 – List of species collected and interactive database of myxomycetes (plasmodial slime molds) for Mt. Arayat National Park, Pampanga, Philippines. *Mycosphere* 2, 449–455.
- Dagamac NHA, Dela Cruz TEE, Rea-Maminta MAD, Aril-Dela Cruz JV et al. 2017 – Rapid assessment of myxomycete diversity in the Bicol Peninsula, Philippines. *Nova Hedwigia* 104, 31–46.
- Dagamac NHA, Rea-Maminta MAD, Batungbacal NS, Jung SH et al. 2015 – Diversity of plasmodial slime molds (myxomycetes) in coastal, mountain, and community forests of Puerto Galera, Oriental Mindoro, the Philippines. *Journal of Asia-Pacific Biodiversity* 8, 322–329.
- Dagamac NHA, Stephenson SL, Dela Cruz TEE. 2012 – Occurrence, distribution and diversity of myxomycetes (plasmodial slime moulds) along two transects in Mt. Arayat National Park, Pampanga, Philippines. *Mycology* 3, 119–126.
- Dagamac NHA, Stephenson SL, Dela Cruz TEE. 2014 – The occurrence of litter myxomycetes at different elevations in Mt. Arayat National Park, Pampanga, Philippines. *Nova Hedwigia* 98, 187–196.
- Dillon WW, Lieurance D, Hiatt DT, Clay K, Flory SL. 2018 – Native and invasive woody species differentially respond to forest edges and forest successional age. *Forests* 9, 381.
- Duelli P, Obrist M, Fluckiger P. 2002 – Forest edges are biodiversity hotspots - also for Neuroptera. *Acta Zoologica Academiae Scientiarum Hungaricae* 48, 75–87.
- Harper KA, MacDonald SE, Burton PJ, Chen J et al. 2005 – Edge influence on forest structure and composition in fragmented landscapes. *Conservation Biology* 19 (3), 768–782.
- Macabago SAB, dela Cruz TEE, Stephenson SL. 2012 – First records of myxomycetes from Lubang Island, occidental Mindoro, Philippines. *Sydowia* 64, 109–118.
- Macabago SAB, Stephenson SL, dela Cruz TEE. 2016 – Diversity and distribution of myxomycetes in coastal and mountain forests of Lubang Island, Occidental Mindoro, Philippines. *Mycosphere* 7, 18–29.
- Müller J, Bußler H, Goßner M, Gruppe A et al. 2007 – Forest edges in the mixed-montane zone of the Bavarian Forest National Park-hot spots of biodiversity. *Silva Gabreta* 13, 121–148.
- Pecundo MH, Dagamac NHA, Stephenson SL, Dela Cruz TEE. 2017 – First myxomycete survey in the limestone forest of Puerto Princesa Subterranean River National Park, Palawan, Philippines. *Nova Hedwigia* 104, 129–141.
- Pfeifer M, Lefebvre V, Peres C, Banks-Leite C et al. 2017 – Creation of forest edges has a global impact on forest vertebrates. *Nature* 551, 187–191.

- Rea-Maminta MAD, Dagamac NHA, Huyop FZ, Wahab RA, Dela Cruz TEE. 2015 – Comparative diversity and heavy metal biosorption of myxomycetes from forest patches on ultramafic and volcanic soils. *Chemistry and Ecology* 31, 741–753.
- Rojas C, Stephenson SL. 2007 – Distribution and ecology of myxomycetes in the high-elevation oak forests of Cerro Bellavista, Costa Rica. *Mycologia* 99, 534–543.
- Sedlock JL, Weyandt SE, Cororan L, Damerow M et al. 2008 – Bat diversity in tropical forest and agro-pastoral habitats within a protected area in the Philippines. *Acta Chiropterologica* 10(2), 349–358.
- Stephenson SL, Kalyanasundaram I, Lakhanpal T. 1993 – A comparative biogeographical study of myxomycetes in the mid-Appalachians of eastern North America and two regions of India. *Journal of Biogeography* 20(6), 645–657.
- Verburg PH, Overmars KP, Huigen MGA, de Groot WT, Veldkamp A. 2006 – Analysis of the effects of land use change on protected areas in the Philippines. *Applied Geography* 26 (2), 153–173.
- Viray AT, Rotap DDS, Migraso LL, Sibbaluca NCI et al. 2014 – Occurrence and diversity of myxomycetes (slime molds) in Polillo Island, Quezon Province, Philippines. *Acta Manilana* 62, 9–17.
- Zheng D, Chen J, LeMoine JM, Euskirchen ES. 2005 – Influences of land-use change and edges on soil respiration in a managed forest landscape, WI, USA. *Forest Ecology and Management* 215, 169–182.