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Myxomycete research in the Philippines: Updates and opportunities

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Abstract

Myxomycetes, commonly known as slime molds, are phagotrophic, eukaryotic organisms that exhibit both fungal and protozoan characteristics. They are widely distributed both in temperate and tropical ecoregions, where they usually occur on dead plant substrates, such as bark, twigs, dried leaves, woody vines, and even decayed inflorescences or fruits. Their unique, diverse morphologies and fascinating life strategies make them ideal model organisms to study life processes. However, despite the high potential diversity in tropical systems, little is known about them particularly in archipelagic countries, such as the Philippines. In fact, previous studies on myxomycetes in the Philippines in the late 70s and early 80s by Reynolds encompassed the most comprehensive listing for the country. A total of 107 species were recorded at that time for the Philippines and roughly 50% of these species represented new records for the country. But the paper was mainly an extensive, annotated species listing. In recent years, myxomycete research in the country has progressed beyond species lists to diversity and ecological studies. Several papers by the UST RCNAS Fungal Biodiversity and Systematics group have documented the occurrence and distribution of slime molds in several habitat types, e.g. in forest parks, coastal and inland limestone forests, lowland mountain forests, and from varied substrata – grass litter, aerial and ground leaf litter, twigs, and bark. These studies updated the list of species of myxomycetes in the Philippines to 150. These also provided baseline information on the ecological patterns and geographic distribution of slime molds in the tropics. This paper presents an update on slime mold research in the Philippines for the 35 years following Reynolds' publication in 1981 and discusses challenges and opportunities for further studies.

Key words – archipelago – checklist – Paleotropics – slime molds – taxonomy

This paper is written in honor of two mycologists who started and contributed significantly to the myxomycete research in the Philippines, Don Reynolds and Irineo J. Dogma Jr.

Introduction

Myxomycetes, also known as plasmodial slime molds or true slime molds, are a small, relatively homogenous group of phagotrophic fungus-like protists (Schnittler et al. 2012, Rojas & Stephenson 2013), with about 1 000 species known and described worldwide (Lado 2005-2015). These species are often abundant in many forested regions, particularly in areas with decaying logs,

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twigs and leaf litter (Stephenson & Stempen 1994, Rojas & Stephenson 2013). These substrata provide them with a sufficient supply of potential food, such as bacteria, yeasts, algae and other microscopic organisms (Lado et al. 2013). Myxomycetes are also recognized as producers of bioactive secondary metabolites. For example, Dembitsky et al. (2005) listed about 100 natural compounds, e.g. fatty acids, lipids, napthoquinone pigments, aromatic compounds, alkaloids and terpenoids, isolated and obtained from several species of myxomycetes. Several of these compounds are known to exhibit antitumor activities, e.g. cyclic phosphatidic acid from *Physarum polycephalum* (Kobayashi et al. 2002) and pyrroloiminoquinone from *Didymium bahiense* (Ishibashi et al. 2001). Myxomycetes are also key components in soil microbiota (Feest & Madelin 1988, Stephenson et al. 2011, Hoppe & Schnittler 2015) and may play a role in maintaining balance in soil ecosystems (Feest 1987; Foissner 1999). Many insects also depend on slime molds for food (Keller & Snell 2002). Despite their numerous applications and important role in nature, the study of the biodiversity of myxomycetes has not been given much attention particularly in the Southeast Asian Paleotropics such as the Philippines, where higher species diversity can be expected (Dagamac et al. 2014).

The earliest report of myxomycetes in the Philippines started from Uyenco (1973) who originally claimed to have published the first report on Philippine myxomycetes. From the 314 specimens collected by Uyenco from Luzon (Quezon City and Laguna) and Mindanao (Basilan and Zamboanga) during the year 1961 to 1973, 18 species were reported belonging to 10 genera. However, Dogma (1975) noted that Martin & Alexopoulos (1969) already credited the Philippines with 22 species in their book entitled *"The Myxomycetes"*. Dogma (1975) then listed 46 species of myxomycetes from 20 genera for the Philippines. The most wide-ranging annotation on Philippine myxomycetes however, was conducted by Don Reynolds in 1981. Reynolds (1981) initially reported the myxomycete collections from Mindanao (Davao, Cotabato and Zamboanga) by E. B. Copeland, and from Luzon by A. D. E. Elmer (Benguet) and E.D. Merrill (Bataan, Manila, Cavite and Laguna). These collections can now be found in the British Museum in London. He also presented an annotated list of 107 species of Philippine myxomycetes based on published and unpublished records. In this list, 53 species were listed as novel records for the country. Myxomycetes that are part of the species list were from the genera *Arcyria*, *Badhamia*, *Ceratiomyxa*, *Clastoderma*, *Comatricha*, *Craterium*, *Cribaria*, *Diachea*, *Dictydium*, *Diderma*, *Didymium*, *Echinostelium*, *Fuligo*, *Hemitrichia*, *Lamproderma*, *Licea*, *Lycogala*, *Metatrichia*, *Perichaena*, *Physarella*, *Physarum*, *Stemonitis*, *Trichia,* and *Tubifera*. Most of these myxomycetes were collected from substrates obtained from several sites in the country: (1) Luzon: Batanes, Ilocos, Mt. Province, Benguet, Bataan, Laguna, Quezon and Palawan, (2) Visayas: Camarines Sur, Sorsogon, Albay, Iloilo, Antique, Leyte, Negros and Cebu, and (3) Mindanao: Agusan, Cotabato, Surigao del Sur, Davao, Zamboanga and Sulu. The 107 myxomycete species reported in this study also included one unidentified species of *Didymium* collected from Cebu that resembles *D. squamulosum,* except that the spores are larger than the typical *D. squamulosum*. Moreover, two myxomycete species listed were currently synonyms of two other myxomycete species found on that same list. *Stemonitis nigrescens* and *S. smithii* are basionyms of *S. axifera* and *S. fusca*, respectively. The list also corresponded to 25% of known species at that time and to 60% of the estimated total myxomycete flora in the Philippines (Reynolds, 1981). Since then, myxomycete survey remained stagnant.

For several decades, there were no published literatures about any myxomycete records since the last comprehensive annotation of Reynolds (1981). Thus in 2009, dela Cruz et al. initially looked at the myxomycetes collection at the Museum of Natural History Mycological Herbarium at the University of the Philippines in Los Baños, Laguna. Myxomycete specimens here were mainly deposited by Dogma, Reynolds and Quimio and belonged to the 21 genera: *Arcyria*, *Ceratiomyxa*, *Cienkowskia* (now identified as *Willkommlangea*), *Clastoderma, Comatricha, Craterium, Cribaria, Diachea, Dictydium, Diderma, Didymium, Fuligo, Hemitrichia, Lamproderma, Lycogala, Perichaena, Physarella, Physarum, Stemonitis, Trichia* and *Tubifera.* Interestingly, the collection also included specimens from the USA, Ecuador and Costa Rica dating from pre-World War II, i.e.

1888 to 1939. These deposited specimens were found to be generally in good condition. On the same year, a specimen found in Anda Island, Pangasinan was identified as a new species, *Craterium retisporum* (Moreno et al. 2009). This new myxomycete species were morphologically erected as new to science because of its distinguishing prominent reticulations found on the spore ornamentation. Dagamac et al. (2010) added five new records of myxomycetes for the Philippines, i.e. *Clastoderma microcarpum, Dianema harveyi, Diderma subasteroides, Physarum leucophaeum,* and *Stemonitis pallida.* These species were collected from bark samples of *Samanea samans* (Jacq) Merr. obtained from 21 different sites in Luzon Island. Furthermore, Dagamac et al. (2011) reported another 5 new records, namely, *Arcyria afroalpina, Collaria arcyrionema, Craterium concinnum, Enerthenema papillatum,* and *Licea biforis* from Mount Arayat National Park, Pampanga. Two additional records, *Lepidoderma tigrinum* and *Perichaena pedata,* were also reported by dela Cruz et al. (2011) as new records for the Philippines. Macabago et al. (2012) reported seven newly recorded species of myxomycetes in the Philippines which were identified as *Arcyria globosa, Collaria rubens, Comatricha robusta, Craterium atrolucens, Lamproderma cacographicum, Oligonema schweinitzii,* and *Perichaena microspora* from Lubang Island, Occidental Mindoro. Additionally, three new records were reported by Kuhn et al. (2013a) from Pangasinan and additional 17 new records by dela Cruz et al. (2014) from Bataan, Cavite and Subic. Recently, Dagamac et al. (2015a) found 8 new records in Bicol Peninsula which now brings the total of myxomycetes recorded in the Philippines to 150.

With such additions to the myxomycete flora accounted for a biodiversity hotspot like the Philippines, this paper (1) provides an updated checklist of the slime molds reported in the Philippines and (2) discusses the challenges and opportunities of engaging one's interest in myxomycete research in the country.

General Study Area

The Philippines is an archipelago composed of 7,107 islands that lies in the Southeast Asian region. Majority of these islands are assumed to be volcanic in origin as it is geographically part of the Pacific Ring of Fire (Hall 2002). General topography in the area is hilly and mountainous typically having constricted coastal plains with abundant rivers, streams and lakes (Catibog-Sinha & Heaney 2006). Every island is endowed with sand beaches, clear coast lines and tropical rain forested mountains wherein the highest point in the country is the peak of Mt. Apo in Mindanao which is ca. 2,954 masl. The country's climate can be described to have a relatively high temperature and humidity with plentiful amount of annual rainfall (Lantican 2001). Similar to other tropical countries, the seasonality in the Philippines is divided into wet and dry seasons. Due to erratic rainfall distribution in different areas in the Philippines, four types of climate were designated on different parts of the archipelago (Philippine Institute for Development Studies, 2005). Type I are characterized of having two pronounced season that is dry during November to April, and wet during all the other months of the year. Areas included in this climate type are part of the Northwestern Luzon (Ilocos region, Western Mt. Provinces, and some part of the Southern Tagalog region). Type II climate has no clear dry period but with a very pronounced rainy season from the months of December to February. There is no single dry month and the minimum annual rainfall occurs during the months of March to May. The Southeastern Luzon areas (Bicol region and Quezon Province) are some examples of localities exposed to such climate type. Type III has no clear seasonality, but is relatively dry from November to April. Areas in the Philippines that experiences such climate type includes the northeastern part of the Ilocos region, scattered islands of the Central Visayas (Aklan, Capiz, Iloilo, Siquijor) and Western part of Mindanao (Agusan, del Sur, Bukidnon, and east Maguindanao). Lastly, Type IV climate is defined to have more or less an evenly distributed rainfall throughout the year and major Visayas islands like Cebu, Bohol, Western Samar and Southern Mindanao (Zamboanga, Davao, Sultan Kudarat) typically experience this climate.

Due to such promising topography and tropical climate distribution in the Philippines, the country is popularly known to be a biodiversity megahotspot (Catibog-Sinha & Heany 2006). With its tropical climate, the country is gifted with numerous forest ecosystems: lowland rainforest, montane - mossy forest, pine forest and coastal, beach or mangrove forest. It is also completely bordered by tropical seas, thus isolating the archipelago from other Asian landmass by hundreds of kilometers of open water. Geological evidence has shown that the Philippines, with the exception of the Palawan and Mindoro regions, have always been isolated (Heaney 1998). Such geographic isolation and ideal climatic conditions resulted in floral and faunal endemicity, as high as 80% (Catibog-Sinha & Heaney 2006). However, with its annual deforestation rate estimated to be 1.4% or about 89,000 hectares removed per year, the country is now listed as one of the most threatened ecosystems on the planet. In 2004, only 24% of the total land area (only about 7.2 million hectares of about 30 million hectares) remained covered with forests (Catibog-Sinha & Heaney 2006). Thus, this necessitates an urgent assessment of the country's biodiversity since many areas remained un- or under-explored and many species remain undiscovered including the myxomycetes.

List of myxomycetes for the Philippines

Table 1 In the myxomycete listing that follows, we present a table for all myxomycetes recorded for the Philippines. Information is provided on the source(s) of each record where the species was first mentioned, along with some general comments. Nomenclature basically follows Lado (2005-2015).

	Myxomycete species	Sources
1	*Alwisia bombarda* Berk. & Broome	First reported as *Tubifera bombarda* (Berk. & Broome) G.W. Martin by Reynolds (1981)
2	*Arcyria afroalpina* Rammeloo	First reported from Dagamac et al. (2011)
3	*Arcyria cinerea* (Bull.) Pers.	First reported from Reynolds (1981)
4	*Arcyria denudata* (L.) Wettst.	First reported from Reynolds (1981)
5	*Arcyria globosa* Schwein.	First reported from Macabago et al. (2012)
6	*Arcyria incarnata* (Pers. ex J.F. Gmel.) Pers.	First reported from Reynolds (1981)
7	*Arcyria insignis* Kalchbr. & Cooke	First reported from Reynolds (1981)
8	*Arcyria magna* Rex	First reported from Reynolds (1981)
9	*Arcyria marginoundalata* Nann.-Bremek. & Y. Yamam.	First reported from dela Cruz et al. (2014)
10	*Arcyria obvelata* (Oeder) Onsberg	First reported as *Arcyria nutans* (Bull.) Grev. by Reynolds (1981)
11	*Arcyria virescens* G. Lister	First reported from Reynolds (1981)
12	*Badhamia affinis* Rostaf.	First reported from dela Cruz et al. (2014)
13	*Badhamia utricularis* (Bull.) Berk.	First reported from Reynolds (1981)
14	*Calomyxa metallica* (Berk.) Nieuwl.	First reported from Reynolds (1981)
15	*Ceratiomyxa fruticulosa* (O.F. Müll.) T. Macbr.	First reported from Reynolds (1981)
16	*Clastoderma debaryanum* A. Blytt	First reported from Reynolds (1981)
17	*Clastoderma microcarpum* (Meyl.) Kowalski	First reported from Dagamac et al. (2010)
18	*Collaria arcyrionema* (Rostaf.) Nann.-Bremek. ex Lado	First reported from Dagamac et. al. (2011) however Reynolds (1981) first reported this species as *Lamproderma arcyrionema*
19	*Collaria rubens* (Lister) Nann.-Bremek.	First reported from Macabago et al. (2012)
20	*Comatricha fragilis* Meyl.	First reported from Dagamac et al. (2015a)
21	*Comatricha longipila* Nann.-Bremek.	First reported from Reynolds (1981)
22	*Comatricha nigra* (Pers. ex J.F. Gmel.) J. Schröt.	First reported from Reynolds (1981)
23	*Comatricha pulchella* (C. Bab.) Rostaf.	First reported from Dagamac et al. (2015a)
24	*Comatricha robusta* (T.N. Lakh. & K.G. Mukerji) Nann.-Bremek. & Y. Yamam.	First reported from Macabago et al. (2012)
25	*Comatricha tenerrima* (M.A. Curtis) G. Lister	First reported from dela Cruz et al. (2014)
26	*Craterium atrolucens* Flatau	First reported from Macabago et al. (2012)
27	*Craterium concinnum* Rex	First reported from Dagamac et. al. (2011)
28	*Craterium leucocephalum* (Pers. ex J.F. Gmel.) Ditmar	Reynolds (1981)
29	*Craterium microcarpum* H.Z. Li, Yu Li & Shuang L. Chen	First reported from Kuhn et al. (2013a)
30	*Craterium minutum* (Leers) Fr.	First reported from Reynolds (1981)
31	*Craterium paraguayense* (Speg.) G. Lister	First reported from Reynolds (1981)

	Myxomycete species	Sources
32	*Craterium retisporum* G. Moreno, D.W. Mitch. & S.L. Stephenson	First reported from Moreno et al. (2009). This new species was described from collections in the Philippines and Western Australia.
33	*Cribraria atrofusca* G.W. Martin & Lovejoy	First reported from Reynolds (1981)
34	*Cribraria cancellata* (Batsch) Nann.-Bremek.	First reported as *Dictydium cancellatum* (Batsch) T. Macbr. by Reynolds (1981)
35	*Cribraria microcarpa* (Schrad.) Pers.	First reported from Reynolds (1981) as *Cribraria pachydictyon* Nann.-Bremek.
36	*Cribraria piriformis* Schrad.	First reported from Reynolds (1981)
37	*Cribraria violacea* Rex	First reported from Reynolds (1981)
38	*Diachea bulbillosa* (Berk. & Broome) Lister	First reported from Reynolds (1981)
39	*Diachea leucopodia* (Bull.) Rostaf.	First reported from Reynolds (1981)
40	*Diachea radiata* G. Lister & Petch	First reported from Reynolds (1981)
41	*Diachea splendens* Peck	First reported from Reynolds (1981)
42	*Dianema harveyi* Rex	First reported from Dagamac et al. (2010)
43	*Dictydiaethalium plumbeum* (Schumach.) Rostaf.	First reported from Reynolds (1981)
44	*Diderma chondrioderma* (de Bary & Rostaf.) G. Lister	First reported from dela Cruz et al. (2014)
45	*Diderma effusum* (Schwein.) Morgan	First reported from Reynolds (1981)
46	*Diderma fallax* (Rostaf.) E.Sheld.	First reported as *Diderma lyallii* (Massee) T. Macbr. by Reynolds (1981)
47	*Diderma hemisphaericum* (Bull.) Hornem.	First reported from Reynolds (1981)
48	*Diderma rugosum* (Rex) T. Macbr.	First reported from Reynolds (1981)
49	*Diderma saundersii* (Berk. & Broome ex Massee) E. Sheld.	First reported from dela Cruz et al. (2014)
50	*Diderma subasteroides* M.L. Farr	First reported from Dagamac et al. (2010)
51	*Didymium anellus* Morgan	First reported from Reynolds (1981)
52	*Didymium anellus* Morgan	First reported from dela Cruz et al. (2014)
53	*Didymium clavus* (Alb. & Schwein.) Rabenh.	First reported from Reynolds (1981)
54	*Didymium flocossum* G.W. Martin, K.S. Thind & Rehill	First reported from Dagamac et al. (2015a)
55	*Didymium iridis* (Ditmar) Fr.	First reported from Reynolds (1981)
56	*Didymium leoninum* Berk. & Broome	First reported from Reynolds (1981)
57	*Didymium megalosporum* Berk. & M.A. Curtis	First reported from Reynolds (1981)
58	*Didymium melanospermum* (Pers.) T. Macbr.	First reported from Reynolds (1981)
59	*Didymium minus* (Lister) Morgan	First reported from Reynolds (1981)
60	*Didymium nigripes* (Link) Fr.	First reported from Reynolds (1981)
61	*Didymium ochroideum* G. Lister	First reported from dela Cruz et al. (2014)
62	*Didymium serpula* Fr.	First reported from dela Cruz et al. (2014)
63	*Didymium squamulosum* (Alb. & Schwein.) Fr. & Palmquist	First reported from Reynolds (1981)
64	*Didymium verrucosporum* A.L. Welden	First reported from Dagamac et al. (2015a)
65	*Echinostelium minutum* de Bary	First reported from Reynolds (1981)
66	*Elaeomyxa miyazakiensis* (Emoto) Hagelst.	First reported from Kuhn et al. (2013a)
67	*Enerthenema papillatum* (Pers.) Rostaf.	First reported from Dagamac et al. (2011)
68	*Fuligo aurea* (Penz.) Y.Yamam.	First reported as *Erionema aureum* Penz. by Reynolds (1981)
69	*Fuligo cinerea* (Schwein.) Morgan	First reported from dela Cruz et al. (2014)
70	*Fuligo septica* (L.) F.H. Wigg.	First reported from Reynolds (1981)
71	*Hemitrichia calyculata (Speg.) M.L.Farr*	First reported from Dagamac et al. (2015a) however Reynolds (1981) first reported this species as *Hemitrichia stipitata* (Massee) T. Macbr
72	*Hemitrichia intorta* (Lister) Lister	First reported from Reynolds (1981)
73	*Hemitrichia leiocarpa (Cooke) Lister*	First reported as *Arcyria leiocarpa* (Cooke) Massee by Reynolds (1981)
74	*Hemitrichia minor G. Lister*	First reported from Dagamac et al. (2015a) however Reynolds (1981) first reported this species as *Perichaena minor* (G. Lister) Hagelst.
75	*Hemitrichia serpula* (Scop.) Rostaf. ex Lister	First reported from Reynolds (1981)
76	*Lamproderma cacographicum* Bozonnet, Mar. Mey. & Poulain	First reported from Macabago et al. (2012)
77	*Lamproderma scintillans* (Berk. & Broome) Morgan	First reported from Reynolds (1981)
78	*Lepidoderma tigrinum* (Schrad.) Rostaf.	First reported from dela Cruz et al (2011)
79	*Licea biforis* Morgan	First reported from Dagamac et al. (2011)

	Myxomycete species	Sources
80	*Licea erecta* K.S. Thind & Dhillon	First reported from Reynolds (1981)
81	*Licea floriformis T.N. Lakh. & R.K. Chopra*	First reported as *Licea floriformis* var. *aureospora* M.T.M. Willemse & Nann.-Bremek by dela Cruz et al. (2014)
82	*Licea operculata* (Wingate) G.W. Martin	First reported from dela Cruz et al. (2014)
83	*Lycogala epidendrum* (L.) Fr.	First reported from Reynolds (1981)
84	*Lycogala exiguum* Morgan	First reported from Reynolds (1981)
85	*Meriderma cribrarioides* (Fr.) Mar.Mey. & Poulain	First reported as *Lamproderma cribrarioides* (Fr.) R.E. Fr. By Reynolds (1981)
86	*Metatrichia vesparia* (Batsch) Nann.-Bremek. ex G.W. Martin & Alexop.	First reported from Reynolds (1981)
87	*Oligonema schweinitzii* (Berk.) G. W. Martin	First reported from Macabago et al. (2012)
88	*Perichaena chrysosperma* (Curr.) Lister	First reported from Reynolds (1981)
89	*Perichaena corticalis* (Batsch) Rostaf.	First reported from Reynolds (1981)
90	*Perichaena depressa* Lib.	First reported from Reynolds (1981)
91	*Perichaena dictyonema* Rammeloo	First reported from dela Cruz et al. (2014)
92	*Perichaena microspora* Penz. & Lister	First reported from Macabago et al. (2012)
93	*Perichaena minor* G. Lister	First reported from Reynolds (1981)
94	*Perichaena pedata* (Lister & G. Lister) Lister ex E. Jahn	First reported from dela Cruz et al. (2011)
95	*Perichaena reticulospora* H.W. Keller & D.R. Reynolds	First reported from Reynolds (1981)
96	*Perichaena vermicularis* (Schwein.) Rostaf.	First reported from Dagamac et al. (2015a) however dela Cruz et al. (2014) first reported this species as *Physarum vermiculare* Schwein. (Schwein.) Rostaf.
97	*Physarella oblonga* (Berk. & M.A. Curtis) Morgan	First reported from Reynolds (1981)
98	*Physaru nucleatum* Rex	First reported from Reynolds (1981)
99	*Physarum album* (Bull.) Chevall.	First reported as *Physarum nutans* Pers. by Reynolds (1981)
100	*Physarum bivalve* Pers.	First reported from Reynolds (1981)
101	*Physarum bogoriense* Racib.	First reported from Reynolds (1981)
102	*Physarum cinereum* (Batsch) Pers.	First reported from Reynolds (1981)
103	*Physarum compressum* Alb. & Schwein.	First reported from Reynolds (1981)
104	*Physarum crateriforme* Petch	First reported from dela Cruz et al. (2014)
105	*Physarum decipiens* M.A. Curtis	First reported from Kuhn et al. (2013a)
106	*Physarum didermoides* (Pers.) Rostaf.	First reported from Reynolds (1981)
107	*Physarum echinosporum* Lister	First reported from Reynolds (1981)
108	*Physarum flavicomum* Berk.	First reported from Reynolds (1981)
109	*Physarum globuliferum* (Bull.) Pers.	First reported from Reynolds (1981)
110	*Physarum gyrosum* Rostaf.	First reported from Reynolds (1981)
111	*Physarum lakhanpalii* Nann.-Bremek. & Y. Yamam.	First reported from dela Cruz et al. (2014)
112	*Physarum leucophaeum* Fr. & Palmquist	First reported from Dagamac et al. (2010)
113	*Physarum melleum* (Berk. & Broome) Massee	First reported from Reynolds (1981)
114	*Physarum nicaraguense* T. Macbr.	First reported from Reynolds (1981)
115	*Physarum notabile* T. Macbr.	First reported from Reynolds (1981)
116	*Physarum oblatum* T. Macbr.	First reported from Reynolds (1981)
117	*Physarum pezizoideum* (Jungh.) Pavill. & Lagarde	First reported from Reynolds (1981)
118	*Physarum polycephalum* Schwein.	First reported from Reynolds (1981)
119	*Physarum psittacinum* Ditmar	First reported from Reynolds (1981)
120	*Physarum pulcherrimum* Berk. & Ravenel	First reported from Reynolds (1981)
121	*Physarum pusillum* (Berk. & M.A. Curtis) G. Lister	First reported from Dagamac et al. (2015a)
122	*Physarum retisporum* G.W. Martin, K.S. Thind & Rehill	First reported from Reynolds (1981)
123	*Physarum rigidum* (G. Lister) G. Lister	First reported from Reynolds (1981)
124	*Physarum roseum* Berk. & Broome	First reported from Reynolds (1981)
125	*Physarum rubiginosum* Fr. & Palmquist	First reported from Reynolds (1981)
126	*Physarum stellatum* (Massee) G.W. Martin	First reported from Reynolds (1981)
127	*Physarum superbum* Hagelst.	First reported from dela Cruz et al. (2014)
128	*Physarum tenerum* Rex	First reported from Reynolds (1981)
129	*Physarum viride* (Bull.) Pers.	First reported from Reynolds (1981)
130	*Reticularia lycoperdon* Bull.	First reported from Reynolds (1981)
131	*Stemonaria fuscoides* Nann.-Bremek. & Y. Yamam.	First reported from Dagamac et al. (2015a)
132	*Stemonaria longa* (Peck) Nann.-Bremek., R.Sharma & Y. Yamam.	First reported as *Comatricha longa* Peck by Reynolds (1981)

	Myxomycete species	Sources
133	*Stemonitis axifera* (Bull.) T. Macbr.	First reported from Reynolds (1981). *Stemonitis smithii* T. Macbr. was reported as a separate species by Reynolds (1981)
134	*Stemonitis flavogenita* E. Jahn	First reported from Dagamac et al. (2015a)
135	*Stemonitis fusca* Roth	First reported from Reynolds (1981). *Stemonitis nigrescens* Rex was reported as a separate species by Reynolds (1981)
136	*Stemonitis herbatica* Peck	First reported from Reynolds (1981)
137	*Stemonitis pallida* Wingate	First reported from Dagamac et al. (2010)
138	*Stemonitis splendens* Rostaf.	First reported from Reynolds (1981)
139	*Stemonitis uvifera* T. Macbr.	First reported from dela Cruz et al. (2014)
140	*Stemonitopsis subcaespitosa* (Peck) Nann.-Bremek.	First reported as *Comatricha subcaespitosa* Peck by Reynolds (1981)
141	*Stemonitopsis typhina* (F.H.Wigg.) Nann.-Bremek.	First reported as *Comatricha typhoides* (Bull.) Rostaf. by Reynolds (1981)
142	*Trichia botrytis* (J.F. Gmel.) Pers.	First reported from Reynolds (1981)
143	*Trichia contorta* (Ditmar) Rostaf.	First reorted as *Hemitrichia karstenii* (Rostaf.) Lister by Reynolds (1981)
144	*Trichia decipiens* (Pers.) T. Macbr.	First reported from Reynolds (1981)
145	*Trichia erecta* Rex	First reported from Reynolds (1981)
146	*Trichia favoginea* (Batsch) Pers.	First reported from Reynolds (1981)
147	*Trichia verrucosa* Berk.	First reported from Reynolds (1981)
148	*Tubifera ferruginosa* Batsch) J.F. Gmel.	First reported from Reynolds (1981)
149	*Tubifera microsperma* (Berk. & M.A. Curtis) G.W. Martin	First reported from Reynolds (1981)
150	*Willkommlangea reticulata* (Alb. & Schwein.) Kuntze	First reported as *Cienkowskia reticulata* (Alb. & Schwein.) Rostaf. by Reynolds (1981)

Discussion

The updated number of myxomycetes records reported for the Philippines is 150. Comparably this number is still much less than the neotropical country, Costa Rica with 208 recorded species (Rojas et al. 2010). It is of course necessary to point out that Costa Rica is more subjected to much more sampling effort both temporally and spatially. Nevertheless, with regards to the other countries in the Southeast Asian region that were surveyed so far for myxomycetes, this number is considerably more numerous than the species listing data reported for Thailand (132 taxa, Ko Ko et al. 2010), Singapore (92, Rosing et al. 2011), Myanmar (67, Ko Ko et al. 2013), Vietnam (57, Tran et al. 2014) and Laos (44, Ko Ko et al. 2012). Since earlier literature about Philippine myxomycetes were mere species lists and no information about diversity and ecological studies had been conducted in most of the myxomycete surveys, classical approaches of rapid myxomycete surveys were employed at the UST RCNAS (University of Santo Tomas - Research Center for the Natural and Applied Sciences).

Surveys conducted in different forest types in the Philippines

For most of this survey in the Philippines, a major habitat type investigated for myxomycetes were the lowland mountain forests in the country. Mt. Arayat in Pampanga was used as a model area to observe the occurrence of myxomycetes along an elevational gradient, seasonality and anthropogenic disturbance (Dagamac et al. 2012; Dagamac et al. 2014). The northern slope of Mt. Makulot in Batangas yielded 21 species belonging to 11 genera (Cheng et al. 2013). So far, the highest report of myxomycete diversity for lowland forests were reported in the collective records from Bicol Peninsula with 62 species of myxomycetes reported, of which one species is a first report of *Stemonaria fuscoides* in the Asian Paleotropics (Dagamac et al. 2015a). National ecoparks in the country were another suitable area for myxomycete surveys because of the intensive environmental protection that at least leads to the development of a secondary type of forest habitat. Baseline information on myxomycete assemblages were conducted in the La Mesa Watershed Ecopark (Macabago et al. 2010), Subic Bay Forest Reserve (dela Cruz et al. 2010), and karst landscape of Quezon National Park (Dagamac et al. 2015b). Furthermore, highland areas were also studied by Kuhn et al. 2013b wherein a total of 25 species were reported in Benguet and forest parks in Baguio City.

The coastal forests of the Philippines were another type of habitat that were intensely surveyed since the archipelagic landscape of the Philippines makes it ideal for island biogeographic study of myxomycetes. Among the coastal islands that were already surveyed were several small islands in Hundred Islands National Park and Anda island in Pangasinan (dela Cruz et al. 2011; Kuhn et al. 2013a), Lubang Island in Occidental Mindoro (Macabago et al. 2012) and Polilio Island in Quezon (Viray et al. 2014). Besides simple surveys, comparative assessments of myxomycete diversity based on their forest types were conducted in the recent years. A comparative study between agricultural land and protected forest area of Mt. Kanlaon in Negros Oriental showed that a heterogenous plant community harbored higher myxomycete diversity than monotypic agricultural plantations (Alfaro et al. 2015). Dagamac et al. (2015c) observed how myxomycete communities are similar in terms of composition between mountain forests and coastal forest habitats in Puerto Galera, a UNESCO Man and Biosphere Reserve. Rea-Maminta et al. (2015) also compared myxomycete assemblages from forest patches of the Philippines that were characterized of having either ultramafic or volcanic soils. Such finding is deemed interesting because despite the higher heavy metal content, ultramafic forest patches yielded higher species diversity as compared to volcanic soils.

Opportunities on myxomycete research in the Philippines

Though admittedly, investigations in terms of ecological patterns for myxomycetes in the Philippines can still be considered in its infancy, several results from different myxomycete surveys have provided interesting insights about the knowledge of Paleotropical myxomycetes. For instance, it has been speculated that myxomycetes follow the intermediate disturbance hypothesis since myxomycete diversity in areas like Bicol Peninsula (Dagamac et al. 2015a) and Puerto Galera (Dagamac et al. 2015c) seem to be affected by either man made activities or natural disturbances. Future research should seek to establish a series of plots along a disturbance gradient in the Philippines to test this hypothesis. In terms of seasonality, the study of Dagamac et al. (2012) in Mt. Arayat National Park is the only one in the country that attempted to compare the diversity of myxomycetes in the clear pronounced wet and dry seasons. The study concluded that the drier season had more species of myxomycetes in comparison to the wet season. It was of course noted that the measures of diversity used in the study were geared more towards standardized substrate sampling design by using solely the moist chamber components. This is due to the fact that erratic rainfalls in the country represent an obstacle in collecting actual fruiting bodies in the field since they can easily be washed away due to strong typhoons that can hit the country during any time of the year. Finding the most appropriate time to search for fruiting bodies in the field is one of the major challenges for myxomycete survey in the Philippines. In order to detect the influence of seasonality on myxomycete diversity, a multi-year survey that utilizes monthly field and substrate collection for moist chambers across a series of standardized plots is recommended. Another aspect that was investigated in Mt. Arayat National Park was the influence of elevation on myxomycete diversity (Dagamac et al. 2014). In that study, no clear pattern was observed since the highest elevation, about 800masl, still had almost the same general vegetation as the lowland elevation (200masl). Such gradients are not as high in comparison to the studies of elevation gradients in Cocos Island, Costa Rica (Rojas & Stephenson 2008). Investigations on highland areas in the Philippines are still unexplored and such surveys in the future could help fill the missing gaps in the understanding of myxomycete ecology for the Paleotropical Asia.

Other studies that utilized myxomycetes in the country

Most of the myxomycete diversity studies conducted in the UST – RCNAS included both basic and applied research goals. Field guides for myxomycetes are rare since many tourists and naturalists fail to recognize microorganisms, as such, local interactive keys (Dagamac et al. 2011) and photoguides (Macabago & dela Cruz 2012) were developed so that myxomycete research could at least be accessible for enthusiast and students. The interactive key based on the DELTA software represented the first for myxomycetes in Southeast Asia. Industrial application of myxomycetes is still unpopular but can be of great potential to many possible research endeavors for the future. The successful in vitro culture of myxomycetes could lead to potential mass production of their unknown natural products. Thus, Macabago & dela Cruz (2014) initialized an attempt to store and preserve cultures of amoeboflagellates from myxomycetes. Moreover, their study had showed that *Physarum compressum* was able to excrete extracellular enzymes such as amylase and protease. A recent study by Rea-Maminta et al. (2015) reported that myxomycetes could have higher levels of chromium and manganese relative to their substrate. This provides preliminary evidence about the potential of myxomycetes for bioabsorption or bioremediation.

Additional insights and concluding remarks

Many areas in the world still remained un- or under-studied for myxomycetes (e.g. Madagascar, Wrigley de Basanta et al. 2013; Papua New Guinea and Caledonia, Kylin et al. 2013). This particularly holds true for the Philippines which so farhave covered only 26 provinces of the 81 total provinces or a total of about 20 large islands and small islets from the 7,107 islands the countryis known for. Many habitat types have not been fully explored, e.g. grasslands, mangrove or beach forest, volcanic forest, mossy or cloud forest, high elevation forests dominated by dwarf trees, to name a few. These all represent unique macrohabitats for myxomycetes. The country is also home to more than 6,000 species of endemic plants. If a single species of myxomycetes may be found restricted to a particular substrata or a host plant, then in theory, this could mean that the country could be home to far more species than previously estimated. Reynolds (1981) in his annotated list estimated that the 107 species recorded for the Philippines at that time represented 60% of the possible species of myxomycetes in the country. Again, if this predication will be accepted as accurate, with the new list of 150 species, adding 43 species in the last 7 years, we are now looking at additional 30 species still waiting to be discovered. Nevertheless, whatever the figures or numbers may be, it is certain that many species of myxomycetes await discovery in the Philippines. Could these unaccounted species be found in many of the unexplored habitats and/or unique substrata in the country? Lastly, the geographic isolation of the Philippines resulted in high endemism among its flora and fauna. Could this also be true for its microbial flora as exemplified by myxomycetes despite their high potential for dispersal? And with some islands previously linked to mainland Asia through the land bridges during the recent and past Ice ages, similarities with some plants and animals in the region have already been documented. Can we also expect similarities in the assemblages of myxomycetes between many parts of Asia and the Philippines? Indeed, the islands of the country offers good sites to explore genetic diversity or study gene flow, speciation, population dynamics or even spore dispersal among myxomycetes. The islands of the Philippines can therefore be a living laboratory to test many hypotheses on key concepts in genetics, ecology and even on interactions between myxomycetes and the endemic host plants or associated insects.

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