

The relationship between species diversity of myxomycetes on litter twigs and forest vegetation types in western Japan

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Myxomycetes mostly inhabit detritus environments of forests in terrestrial ecosystem. However, differences in myxomycete communities among various vegetation types of local forests have been little known. We examined the myxomycete communities on litter twigs in six types of forests (three types of natural and three types of country-side forests) due to clarify characteristics of the myxomycete diversity in western Japan. Fallen twigs were collected from the forest floor under trees dominating the canopy in all six forests, and moist chamber cultures were established in 640 Petri dishes. In total, 42 taxa belonging to 19 genera were recorded, of which only four species were common to all six forests. The natural broad-leaved evergreen forest (21 taxa) and the country-side pine forest (7 taxa), respectively, showed the highest and lowest α -diversities for myxomycete communities. The species diversity in country-side forests was lower than that in natural forests. Non-metric multidimensional scaling revealed that the myxomycete communities in natural forests distinctively had characteristic community structures and those in country-side forests resembled those in the adjacent natural forests, except in the country-side pine forest. To our knowledge, this is the first comprehensive study on the relationships between forest types and myxomycete communities living on litter twigs in Japan; these findings indicate the potential effects of geographical location and forest types, including biodiversity decreasing influenced by anthropogenic activity.

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Introduction

Myxomycetes, or slime molds, are amoeboid protists that inhabit decaying plant materials in terrestrial ecosystems; they use substrates,

such as coarse woody debris, leaf litter, twigs, dung, and soil (Stephenson *et al.* 2008^a, 2011, Novozhilov *et al.* 2017). They may play a substantial role in nutrient cycling during detritus degradation (Urich *et al.* 2008) as they

feed on organisms, such as bacteria and fungi, as well as organic matter in the forest detritus. Their life cycle comprises different trophic stages: amoeboflagellates and plasmodia, which feed on bacteria and organic material, and the development of fruiting bodies, which then disperse over long distances via air (Schnittler *et al.* 2017). Myxomycetes can broadly spread and grow in favorable microhabitats in various terrestrial ecosystems. The fruiting bodies have morphological features that are used to classify myxomycete species based on microscopic observation. The fruiting bodies differ among species and provide a basic unit to quantify species richness and abundance as well as facilitate research on the occurrence, ecology, and biogeography of myxomycetes (Novozhilov *et al.* 2017).

Litter on the forest floor is generally diverse and preserves microorganisms inhabiting detritus, including myxomycetes (Walker *et al.* 2019). Substrate types, such as coarse woody debris, fallen twigs, and leaf litter in forests, cause differences in myxomycete communities (Novozhilov *et al.* 2017, Rollins & Stephenson 2012), processes and periods of decomposition, and nutrient availability (Matumoto & Nijima 1993, Yoneda 2000). Fallen twigs have been recognized as ecologically distinct habitats (Stephenson 1989, Stephenson *et al.* 2008^b). Thus, fallen twigs in various forest types constitute an important ecological aspect of myxomycetes and forest ecosystem function. However, studies investigating fallen twigs as habitats for myxomycetes remain lacking.

Important factors that may locally influence myxomycete habitat likely include environmental differences, such as geographical location (Takahashi & Hada 2010), topography (Takahashi 2017, Takahashi *et al.* 2020), and anthropogenic differences (Takahashi & Yano 2021) in Japan. Recent natural disturbances and forest degradation caused by urbanization may have greatly influenced the local ecosystems (Davison *et al.* 2021, Sejati *et al.* 2018). However, the effects of these factors have not been fully investigated, though anthropogenic activity does influence myxomycete species diversity as well as that of every organism on a global scale. Myxomycete diversity has decreased with the

loss of forest area along river courses (Takahashi 2021). Current disturbances caused by forest use have resulted in habitat loss for myxomycetes, leading to differences in the abundance of fruiting bodies (Dagamac *et al.* 2015, Macabago *et al.* 2017, Rojas & Stephenson 2013). Around Mt. Fuji in Japan, a world cultural heritage area, myxomycetes inhabiting the bark of living *Cryptomeria japonica* trees have been affected by declining forest coverage as a result of human activity (Takahashi & Yano 2021). The present study thus examines whether myxomycete inhabitation is affected by long-term human use of forests compared with that in the neighboring natural forests.

The Chugoku and Shikoku regions in western Japan contain three types of natural, broad-leaved deciduous, coniferous, and broad-leaved evergreen forests (Yamanaka 1990). Their foothills also have country-side forests, which were used by people for their livelihoods and for the forest industry until approximately 60

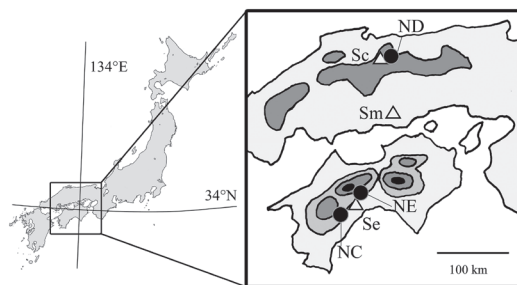


Fig. 1. Location of the six survey sites in the Chugoku–Shikoku region, Japan. ● indicates natural forests and Δ indicates secondary forests. ND: natural broad-leaved deciduous forest dominated by *Fagus crenata* in Mt. Daisen, Tottori Prefecture; Sc: country-side forest of *Pinus densiflora* in the foothills of Mt. Daisen; Sm: country-side mixed forest of evergreen and deciduous trees in Kurashiki, Okayama Pref.; NE: natural broad-leaved evergreen forest at Yokogurayama, Kohchi Pref.; Se: country-side forest in broad-leaved evergreen forest; NC: coniferous natural forest dominated by *Abies firma*. The vegetation types are color-coded in the figure, and from the lowlands, broad-leaved evergreens, high conifers in the transition zone, broad-leaved deciduous trees, and sub-alpine coniferous forests are distributed.

Table 1. Information on vegetation, geographical and climatic variables in surveyed forests. Mt: annual mean temperature, Pre: annual mean precipitation.

Vegetation type	Latitude (N°)	Longitude (E°)	Altitude (m)	Mt (°C)	Pre (mm)	Sampled trees
Natural forests						
Deciduous (ND)	35.389587	133.528630	803	12.4	2851	<i>Cryptomeria japonica</i> , <i>Fagus crenata</i> , <i>Quercus crispula</i>
Evergreen: (NE)	33.534998	133.204600	755	12.7	2780	<i>Quercus acuta</i> , <i>Castanopsis sieboldii</i> , <i>Cryptomeria japonica</i>
Coniferous (NC)	33.345251	132.963546	491	13.0	2728	<i>Abies firma</i>
Country-side forests						
Coniferous (Sc)	35.368157	133.502820	578	13.6	2851	<i>Pinus densiflora</i> , <i>Quercus crispula</i>
Mixed (Sm)	34.639196	133.817490	26	15.8	1042	<i>Quercus glauca</i> , <i>Quercus variabilis</i> , <i>Prunus × yedoensis</i>
Evergreen: (Se)	33.532023	133.243300	66	16.4	2780	<i>Castanopsis sieboldii</i> , <i>Quercus glauca</i> , <i>Prunus × yedoensis</i>

years ago (Yano 1988). In the present study, we examined myxomycete distribution in different forest types in the Chugoku–Shikoku region of western Japan to determine whether forest type (*i.e.*, natural forest and country-side forest) and anthropogenic activity influence myxomycete communities and species inhabitation. We selected sites in forest areas located in the Chugoku–Shikoku region, which were representative of typical forest communities with respect to both vegetation and site conditions. The highest mountain in western Japan, Mt. Ishizuchi (1,982 m asl.), located in the Chugoku–Shikoku region. It includes surveyed sites including the natural deciduous forests of *Fagus crenata*, which are protected in the limited mountain areas above 800 m in elevation at Mt. Daisen (1729 m asl) in the Tottori prefecture (Miyawaki 1982, 1983); the natural broad-leaved evergreens in Yokogurayama (above 800 m asl) at the Takaoka-gun, Kochi prefecture; and the transition forest located between these, with coniferous forests dominated by *Abies* species in the Kochi prefecture (Uchiyama 2003). The foothills and lowlands around these mountains have natural forests including broad-leaved deciduous, evergreen, and/or coniferous forests; these are country-side forests that have been extensively affected by human activity.

Fallen twigs on forest floors are recognized as ecologically distinctive habitats of myxomycetes and thus, species living on twigs from dominating

trees in the forests were considered to represent the differences between natural and human used forests; these were assessed using the moist chamber culture method (Schnittler & Stephenson 2000, Stephenson *et al.* 2008^b).

Materials and Methods

1. Survey sites and twig sampling

Six survey sites were established in different locations in the Chugoku and Shikoku regions (Fig. 1). There were three natural forests with varying forest types and three country-side forests neighboring natural forests or town areas. Information in surveyed forests was listed in Table 1. The natural forests were a broad-leaved deciduous type dominated by *Fagus crenata* Blume (Fig. 2A) and *Quercus crispula* Blume, partially including *C. japonica* D. Don. (Miyawaki 1982) (Daisen-cho, Tottori prefecture, 35.389587° N, 133.52863° E, 803 m asl). The natural coniferous forest consisted of *Abies firma* Siebold et Zucc. and *Tsuga sieboldii* Carriere and located in the transition area between the evergreen and deciduous vegetation zones in Shikoku region; the sampling sites were at Takatoriyama (Yusuhara-cho, 33.345251° N, 132.963355° E, 491 m asl) and at Kajigadani, Ohdou Shimanto-cho, Kochi prefecture (33.289696° N, 132.859877° E, 578 m asl). The natural broad-leaved evergreen forest was dominated by *Q. acuta* Thunb. and



Fig. 2. Forest landscapes, moist chamber cultures, and myxomycete fruiting bodies. **A**: natural broad-leaved deciduous forest dominated by *Fagus crenata* in Mt. Daisen; **B**: country-side coniferous forest dominated by *Pinus densiflora*; **C**: moist chamber culture of twigs; **D**: white plasmodium occurred on twigs in MC; **E**: fruiting bodies of *Arcyria cinerea* formed on the wall of a Petri dish, **F**: fruiting bodies of *Cribraria microcarpa*.

Castanopsis sieboldii (Makino) Hatus. ex T. Yamaz. et Mashiba subsp. *sieboldii*, as well as large naturally inhabiting coniferous *C. japonica* trees (Miyawaki 1983). The three country-side forests were located adjacent to villages or towns and neighboring the natural forests; these have been traditionally used for forest resources. The country-side coniferous forest dominated by *Pinus densiflora* was shown in Fig. 2B.

Temperature and precipitation data for the survey sites were obtained from the Japanese Meteorological Agency. Observations were taken from neighboring regions (<http://www.data.jma.go.jp/obd/stats/etrn/index.php?sess>, accessed on January 5, 2022) and were analyzed based on a temperature decrease rate of -0.55 °C per 100 m increase in elevation. The annual mean temperature and regional mean annual precipitation across the survey sites is shown in Table 1.

We performed sampling under the dominant trees in the forests and collected twigs of approximately 0.5–1.5 cm in diameter from around each tree. Although the supply of fallen twigs in the study region is sporadic in time and space throughout the year, the twigs remain on the forest floors for several years (Ishii *et al.* 1976). The twigs were selected from those in contact with the litter surface and had remaining bark and were randomly sampled at different decay states ranging from slightly to moderately rotten; fresh and soft, highly rotted wood was excluded. The twigs were then placed in paper bags.

2. Myxomycete cultures

We used the moist chamber culture technique to identify myxomycetes; this method has been previously described as useful for observing the small fruiting bodies of myxomycetes on twigs (Stephenson *et al.* 2008^b). The twig samples of dominant trees were air-dried for 1–2 weeks at room temperature (20–25 °C). The moist chamber cultures (Fig. 2C) were then established in 20–50 plastic Petri dishes (9 cm in diameter) per tree at a time and incubated in humid conditions. Twig samples were cut into 3–8 cm long pieces. Approximately 10 g of twigs (dry weight) was placed on a clean filter paper in each Petri dish. Each dish was then filled with approximately 30 mL of distilled water (pH 6.9), covered,

and soaked for a week at 23 °C. The pH of the resulting exudate was measured using a compact pH meter (Horiba, Kyoto, Japan). The twig pH was determined as the median per tree and averaged in each forest. Next, the water was slowly poured from the dishes, and the dishes were incubated for over two months at 23 °C to stimulate sporulation. After two months the cultures were maintained with their lid half open to slowly dry the twig samples. Myxomycetes have a short life cycle and tend to sporulate within 10–70 days in moist chamber cultures; therefore, the fruiting bodies were assessed at approximately 50–80 days using a dissecting stereomicroscope (Nikon SMZ1000) (Wrigley de Basanta *et al.* 2000). The percentage of positive cultures was calculated by dividing the number of dishes with successful cultures (*i.e.*, those with plasmodia or sporangia) by the total number of dishes. The number of myxomycete species identified per tree species and accumulated per forest was recorded, and species abundance was estimated as the number of positive culture dishes in which sporangia appeared.

Myxomycete species classification was performed as described by Yamamoto (1998), and the nomenclature from the most recent literature was followed (Lado 2005–2022). Voucher specimens were prepared using separate paper boxes for each species. The twig containing myxomycete fruiting bodies was glued to the bottom of each box, and the collection boxes were stored in the laboratory.

3. Data analyses

Species richness and abundance were recorded for each sample tree and summed according to the survey forest. Sampling adequacy (percentage of exactitude) was assessed by dividing the number of taxa observed (S_{obs}) within a tree species by the estimated number of taxa (S_{est}) (Chao 1, Chao 1984) using PAST software (Hammer *et al.* 2001, <http://folk.uio.no/ohammer/past/>), using the formula, $S_{obs} / S_{est} \times 100$.

To quantify the myxomycete α diversity in each forest, the Shannon–Wiener diversity index H' (Shannon and Weaver 1963) and the equitability index J' (Pielou, 1966) were determined as described in previous studies (Stephenson, 1989). β diversity, which was used

to estimate the similarity between communities (Akesaka *et al.* 2021), was calculated as the Bray–Curtis dissimilarity (Doi & Okamura 2011). Species relative abundance was calculated by dividing a given species abundance by the cumulative abundance of the community for that forest and was similarly calculated for the total of all communities. We defined dominant species as those with $\geq 10\%$ relative abundance at the total community level and frequent species as those with $\geq 1.8\%$ relative abundance (five abundances).

The similarity of six myxomycete communities was analyzed by non-metric multidimensional scaling (NMDS; Kenkel & Orlóci 1986) using PAST software. This software has been used effectively in a similar previous study (Takahashi *et al.* 2018). NMDS is based on Bray–Curtis dissimilarities (Bray & Curtis 1957), where higher values (to a maximum of 1.0) indicate greater dissimilarity between communities with respect to species composition and abundance. The scores of the first two NMDS axes were then checked for correlations with twig pH and biogeographical variables, including latitude, longitude, elevation, mean temperature, and annual precipitation to identify important environmental factors for subsequent analyses. The association among environmental factors (Table 1) was assessed using correlation analysis performed with Excel Statistics version 7.0 (Esumi Co., Ltd, Tokyo), to estimate the association between myxomycete communities and biogeographical trends. Cluster analysis (Ward's method) was performed to group the myxomycete communities based on NMDS scores for the first two axes.

Results

Myxomycete communities on twigs

Fallen twigs from canopy trees were sampled from one or more tree species, according to the dominating tree species in the surveyed forests. Sixty or more moist chamber cultures were performed per forest. Myxomycetes sporangia developed following plasmodium appearance (Fig. 2D), and fruiting was observed in 35 % of culture dishes in all 640 cultures (Table 2). In total, 42 myxomycete taxa were identified at the six survey forests (Table 3). The species diversity

of the myxomycete community on twigs was $H' = 2.73$ ($J' = 0.73$) under 76 % exactitude for a total of 55 taxa predicted using Chao-1 (Table 2). The following four species were common to all forests, in descending order: *Arcyria cinerea* (Bull.) Pers. (relative abundance, 28.6 %) (Fig. 2E), *Diderma chondrioderma* (de Bary & Rostaf.) G. Lister (representing 14.9 % of all records), *Cribraria microcarpa* (Schrad.) Pers. (representing 9.8 % of all records) (Fig. 2F), and *Clastoderma debaryanum* Blytt (representing 4.3 % of all records). Other abundant species included *Stemonaria gracilis* Nann-Bremek. & Y. Yamam. (relative abundance, 7.6 %) and *Physarum pusillum* (Berk. & Curt.) G. Lister (relative abundance, 3.3 %), which were then followed by the remaining 36 taxa.

Myxomycete communities associated with forest types

The α -diversities of myxomycete communities in natural forests (Table 2) were as follows: evergreen forest (21 taxa, diversity index $H' = 2.70$, and equitability index $J' = 0.89$), deciduous forest (13 taxa, $H' = 1.73$, and $J' = 0.67$), and coniferous forest (12 taxa, $H' = 2.00$, and $J' = 0.80$). Further, the α -diversities of myxomycete communities in country-side forests were as follows: evergreen forest was 18 taxa ($H' = 2.46$, $J' = 0.85$), mixed forest with deciduous and evergreen trees (Sm) was 18 taxa ($H' = 2.33$, $J' = 0.80$), and coniferous forest was the lowest of 7 taxa ($H' = 1.67$, $J' = 0.86$). The six communities of different forests were compared in order with the species diversity and equitability (Fig. 3). The country-side evergreen forest (Se) and mixed forest (Sm) located between both natural forest types of NE and ND demonstrated a medium level of diversity, but country-side coniferous forest (Sc) separated from the rest of the forests (Fig. 3). The natural forests had higher diversity than that in the neighboring country-side forests. Species diversity in the six communities tended to decrease from natural forests to country-side forests.

The different six communities were ordinated using NMDS and plotted (Fig. 4). Cluster analysis indicated two groups of the communities bounded by wavy ellipses. The natural broad-leaved evergreen forest (NE) differed from the

Table 2. Results of moist chamber cultures (MCs) indicating twig pH, species diversity, and exactitude of myxomycete communities in natural and country-side forests.

Forest types	Natural forests			Country-side forests			Whole survey
	Deciduous (ND)	Coniferous (NC)	Evergreen (NE)	Coniferous (Sc)	Mixed (Sm)	Evergreen (Se)	
Tree species	3	1	3	2	3	3	10
MCs	100	60	190	80	90	120	640
Mean pH	5.5	5.1	4.7	5.2	5.3	5.3	5.1
Range of pH	4.4–6.8	4.3–6.2	4.0–5.6	4.4–6.0	4.9–6.6	4.0–6.9	4.0–6.9
Positive cultures (%)	41	43	24	26	47	38	35
Myxomycete diversity							
Taxa	13	12	21	7	18	18	42
Species diversity (H')	1.73	2.00	2.70	1.68	2.33	2.46	2.73
Equitability (J')	0.67	0.80	0.89	0.86	0.80	0.85	0.73
Chao-1	31	15	35	9	29	27	55
Exactitude (%)	42	83	60	82	62	66	76

natural broad-leaved deciduous forest (ND) but was near the natural coniferous forest (NC). The county-side evergreen forest in Kochi prefecture (Se) was closely situated to the natural evergreen forest (NE). The county-side mixed forest (Sm) in Kurashiki City, in the southern part of Okayama prefecture, was close to the natural broad-leaved deciduous forest (ND) in Mt. Daisen, Tottori prefecture. However, the county-

side coniferous forest (Sc) dominated by *P. densiflora* and *Q. crispula* in the foothills of Mt. Daisen was distant from ND or NE, even though its location was adjacent to that of ND. Thus, spatially close locations likely contained similar myxomycete community structures compared with those in geographically distant locations, but the tree types constituting the forests affected myxomycete diversity and similarity between communities.

The arrangement of the six communities was determined based on correlations with environmental parameters (Table 4). Scores of the first two axes in NMDS and the geographical location exhibited negative correlation coefficients with the first axis (latitude $r = -0.764$, longitude $r = -0.643$, and altitude $r = -0.096$). However, this correlation was not statistically significant, and climatic factors (annual mean temperature and annual precipitation) also indicated low coefficients. Thus, no remarkable association was obtained between myxomycete communities and any of the environment factors including twig pH.

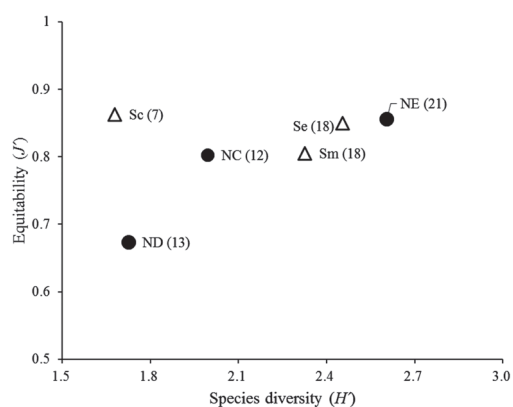


Fig. 3. Species diversity (H') and equitability (J') of six myxomycete communities, ● indicates natural forests, △ indicates secondary forest. NE: natural broad-leaved evergreen forest; ND: natural broad-leaved deciduous forest; NC: natural coniferous forest; Sc: country-side coniferous forest; Sm: country-side mixed forest with deciduous and evergreen trees; Se: country-side broad-leaved evergreen forest. Numbers in brackets indicate the number of taxa.

Discussion

The highest myxomycete diversity on litter twigs occurred in natural broad-leaf evergreen forests in western Japan. The myxomycete communities among three different natural forests were presumed to be of original similarity

Table 3. (continued)

Taxa	Forest type			Country-side forests			Total	Relative abundance (%)
	Deciduous (ND)	Evergreen (NE)	Coniferous (NC)	Coniferous (Sc)	Mixed (Sm)	Evergreen (Se)		
<i>Physarum oblatum</i> T. Macbr.						1	1	0.4
<i>Stemonaria laxa</i> Nann.-Bremek. & Y. Yamam.			1				1	0.4
<i>Stemonitis fusca</i> var. <i>nigrescens</i> (Rex) Torred	1						1	0.4
<i>Stemonitis herbatica</i> Peck		1					1	0.4
<i>Stemonitis smithii</i> T. Macbr.			1				1	0.4
<i>Stemonitis splendens</i> Rostaf.					1		1	0.4
<i>Trichia botrytis</i> (J. F. Gmel.) Pers.			1				1	0.4
Number of colonies	47	53	45	20	51	60	276	100

Table 4. Correlation coefficients among NMDS scores of myxomycete communities in six forest types and environment variables.

	Axis 1	Axis 2
Number of tree species	0.135	-0.566
Number of cultures	0.390	0.114
Latitude	-0.764	-0.477
Longitude	-0.643	-0.661
Altitude	-0.096	0.201
Mean temperature	0.115	-0.214
Precipitation	0.319	0.462
Twig pH	-0.168	-0.726

based on biogeographical location in the present survey region (Fig. 4). Spatially close myxomycete communities exhibited similar structures as shown between natural broad-leaved evergreen forest (NE) and natural coniferous forests (NC). The difference of vegetation types also influenced dissimilarity between the communities. The three communities of country-side forests were considerably affected by geographical distances and difference of vegetation types. The original forests impacted by anthropogenic activity were presumed to cause diversity loss of myxomycete communities as likely degraded as in the country-side forests in geographically neighboring natural forest (Figs. 3 & 4). The country-side forests surveyed in present study were left unused since the 1960s

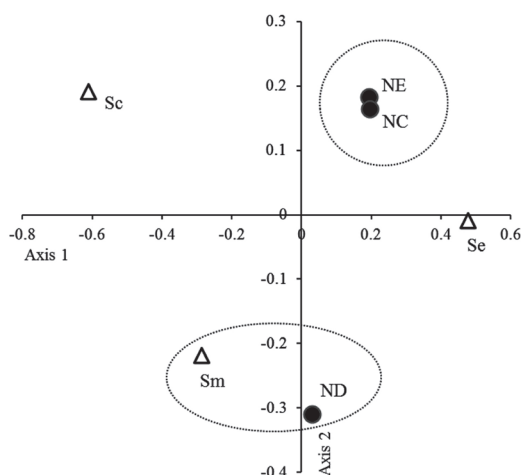


Fig. 4. Ordination plots of six forest types in natural and secondary forests analyzed using NMDS; the stress value was 0.080. The coefficient of determination for the first axis was $r^2 = 0.814$, and that for the second axis was $r^2 = 0.010$. As in Table 1 and Fig. 3, ● and Δ indicate natural forest and secondary forest, respectively. Ovals with a dashed line indicate similar groups with 70 % reliability in the cluster analysis (Ward's method). ND: natural broad-leaved deciduous forest dominated by *Fagus crenata* in Mt. Daisen, Tottori Pref.; Sc: country-side forest of *Pinus densiflora* in the foothills of Mt. Daisen; Sm: country-side mixed forest of evergreen and deciduous trees in Kurashiki, Okayama Pref.; NE: natural broad-leaved evergreen forest at Yokogurayama, Kohchi Pref.; Se: country-side forest in the broad-leaved evergreen forest; NC: coniferous natural forest dominated by *Abies firma*.

because of fuel use revolution, whereas species diversity of myxomycetes cannot be considered restored likely natural forests.

A change in vegetation from natural broad-leaved deciduous forest to country-side pine forest induced a strong impact on myxomycete community and diversity decreasing. The country-side mixed forest comprised deciduous and evergreen trees maintaining intermediate diversity, suggesting that forest vegetation was an important factor for species inhabitation and suitability of myxomycetes. Although the six different forests surveyed did not indicate a direct correlation with geographical location and climates (Table 4), the differences in myxomycete communities were suggested to be because of differences in biogeographical location, forest vegetation types, and anthropogenic impact.

Complex environmental variables derived from the geohistorical geography and climate influence the origin of forest vegetation (Momohara 2017). The spatial distribution patterns of myxomycetes also associated with geohistorical host tree diversification can be studied using *C. japonica* on the myxomycetes living on the bark (Takahashi 2020). Myxomycete distribution is successfully related to differences in climate and/or vegetation on a global scale, and to the ecological differences that exist among individual habitats on a local scale (Stephenson *et al.* 2008^a). The vegetation differences among natural forests on a local scale provide specific habitats for myxomycetes (Takahashi & Harakon 2010). The altitudinal differences affected the myxomycete communities on the bark of *C. japonica* trees in western Japan (Takahashi 2017), and the topographical differences in the present region influenced the communities on the bark of living *C. japonica* (Takahashi *et al.* 2020). In Philippines, the highest taxonomic diversity was recorded for study sites at the highest elevations (*i.e.*, 700–800 m asl) in a secondary deciduous sub-tropical forest at Mt. Arayat National Park, using moist chamber cultures of leaf litter and twigs, of which substrates yielded a total of 30 species of myxomycetes (Dagamac *et al.* 2014). The results of the present study extended understanding, that is, the community structure of myxomycetes responds to local environmental variables, including human impact such as

country-side or natural forests.

We found that myxomycete species richness and species diversity (H') decreased in country-side forests compared with that in the neighboring natural forest, for example, the broad-leaved deciduous forests in Mt. Daisen exhibited a decline from 13 to seven taxa (H' from 1.73 to 1.68); the broad-leaved evergreen forest areas in Yokogurayama showed a decrease from 21 to 18 taxa (H' from 2.70 to 2.46), and the mixed forest in the urban area recorded 18 taxa ($H' = 2.33$). It was suggested that the impact of anthropogenic activities influences microorganisms as well as animals and plants (Davison *et al.* 2021). The change identified in myxomycete communities between mountain forests and banana plantations in Vietnam (Novozhilov *et al.* 2019) may indicate the effect of ecological distance on detritus decomposition and the influence of human activity.

Deforestation derived from human activity was found to reduce the species diversity of corticolous myxomycetes along the downstream section of a river (Takahashi 2021) or in the developed region around Mt. Fuji (Takahashi & Yano 2021). Forest fragmentation in southeastern Peru has also caused habitat loss and demonstrated that differences in forest structure contributed the most to the differences in myxomycete fruiting body abundance among forest types (Rojas & Stephenson 2013). Overall, these studies indicate that forest ecosystems individually establish inherent functions within decomposing detritus and in the microbial communities, including myxomycetes, in a forest.

In forest ecosystems, myxomycetes are assumed to play important nutrient cycling roles in complex food webs (Gessner 2010). Changes in the species diversity of detritivores within and across trophic levels can significantly alter decomposition (Gessner 2010); further, low diversity slows the rate of litter decomposition (McLaren 2014). This suggests that differences in the species diversity of myxomycetes between different forest types, such as natural or country-side, and broad-leaved evergreen or deciduous, are related to divergent habitat conditions and affect certain ecological functions. The diversity of the myxomycete community may associate

with functional interactions with other microbes and is important to preserve balance in the forest ecosystem and sustainable carbon cycle. Overall, this is the first comprehensive study on the distribution pattern of myxomycetes living on litter twigs in different forest types; these findings suggest the potential influence of anthropogenic activity on myxomycetes and forest ecosystem.

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高橋和成・福島実奈・荒山幸美・松田実桜・木立侑里・田中福人・南耕太郎・富永 晃・立石京子・原紺勇一：西日本における落枝生変形菌の種多様性と森林タイプとの関係

変形菌の多くは森林の枯死木や落葉・落枝などの腐植で生活するが、森林タイプの違いがどのように変形菌群集に影響を与えているのかは十分に分かっていない。落枝は変形菌にとって生態的なニッチになっているため、森林の優占種の落枝で生育する変形菌（落枝生変形菌）の分布を異なる森林タイプ間で比較した。調査地は、西日本の中国・四国地方に立地する6つの異なる森林タイプ（3つの天然林と3つの里山林）を選定し、それぞれの落枝生変形菌群集の類似性、および天然

林と里山林との比較をした。森林ごとに採取した優占樹種の落枝を全体で640枚のペトリ皿で湿室培養し、発生した変形菌子実体コロニーの数と出現種を記録した。出現種は全体で19属42種であったが、6つの森林タイプに共通して出現したのは4種のみであった。天然林の常緑広葉樹林で21種が出現し、種多様性が最も高くなった。一方、里山のアカマツ林では7種しか出現しないなど、里山林では種多様性が低下した。非計量多次元尺度構成法で変形菌群集を序列化すると、地理的に近接する森林間では類似性が高いが、森林タイプにより個別の群集構造を形成した。本研究では、西日本の森林タイプの違いによる落枝生変形菌の分布パターンが明らかになり、人間活動の影響を受けた里山林で変形菌の多様性が低下していることが分かった。

