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Myxomycetes (slime moulds) of arid to semi-arid areas of northwest New South Wales, Australia

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Abstract: Myxomycetes (plasmodial slime moulds) were studied along an east-west traverse extending across the arid and semi-arid zones in northwest New South Wales bounded by Lake Cargelligo (400 mm annual rainfall), Bourke (400 mm annual rainfall), Tibooburra (200 mm annual rainfall) and Menindee (250 mm annual rainfall). Samples of tree bark were collected from a range of trees, and subsequently myxomycetes were obtained in the laboratory with the use of the moist culture method. A total of 43 species were recognized. The assemblages of myxomycetes recorded did not change significantly across these climate zones, and, for samples with a reasonable number of species present, there was little difference in diversity due to tree-bark type. The assemblage of species present along this traverse is similar to arid and semi-arid zone tree bark assemblages elsewhere in Australia, which is consistent with the occurrence of one assemblage throughout.

About half of this assemblage consists of widely distributed species likely to be recorded anywhere in the world (cosmopolitan), although these species are found in relatively few samples. The other half of the assemblage is made up of species with a more restricted distribution (generally found in one region of the world or relatively rare worldwide); these species were found in most samples. These restricted distribution species have centres of distribution at a similar latitude and climate in the northern hemisphere.

The assemblage of species associated with bark in the higher rainfall areas of Australia has some of the species of the arid and semi-arid zones; it has most of the widely distributed species and very few of the restricted distribution species. The boundary zone between the two assemblages of species is likely to be near the outer margin of the semi-arid zone.

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Introduction

Myxomycetes (plasmodial slime moulds) are a small group of fungus-like organisms with a two-stage life cycle; a single nucleate phase (amoeboid or flagellated), and a multi-nucleate (single cell) phase starting as a plasmodium and ending as a fruiting body (containing spores) generally 0.5-2 mm high. Identification is based on the dried fruiting body.

During the last 10 years there have been numerous studies of the myxomycete biota of the world's arid and semi-arid areas (e.g., Novozhilov & Schnittler, 2008; Lado et al., 2011) and many of these areas have been found to have more species than expected (Lado et al., 2011). However, in arid and semi-arid areas in Australia, myxomycetes have been poorly studied.

Pre-1995 studies of Australian myxomycetes were summarised by Mitchell (1995). Subsequent work, involving both field collections and moist chamber culture collections, has been directed primarily towards increasing the number of species known from Australia, their regional distributions and host substrates such as wood, bark and litter (Ing & Spooner, 1994; McHugh et al., 2003; Jordan et al., 2006); Rosing et al, 2007; Davison et al, 2008; McHugh et al 2009; Knight & Brims, 2010). Studies have also been carried out on myxomycetes associated with lianas (Wrigley de Basanta et al., 2008) and with snowbanks (Stephenson and Shadwick, 2009). Most of this work has been based on collections from the higher rainfall areas (>600 mm mean annual rainfall) around the edge of the continent. There has been little study of low rainfall areas; the information available consists of specimens deposited in herbaria and one published study of the myxomycetes of the northern Simpson Desert (Davison et al., 2008).

The arid and semi-arid areas comprise about 75% of the Australia continent (Fig. 1) and their extent is a function of both rainfall and potential evaporation. This is expressed in the Köppen climate classification and its modifications (McKnight & Hess, 2000). The arid area is hot arid (BWh), and the semi-arid area hot in the north (BSh) and cool in the south (BSk). These areas are mapped using the latest climate data is the 'Seasonal rainfall zones of Australia' of the Bureau of Meteorology (www.bom.gov.au). In the north, the semi-arid area is bounded by 350-650 mm mean annual rainfall and in the south by 250–500 mm annual rainfall, so the arid zone is bounded in the north by the 350 mm annual rainfall, and in the south by 250 mm annual rainfall. The minimum mean annual rainfall in central Australia is about 150 mm. Associated with this increase in aridity toward the centre of Australia is an increase in mean maximum temperature, and an increase in the variability in rainfall. Plants and other organisms may also be affected by two north-south changes across Australia: (1) decrease in mean average temperature away from the equator, and (2) the change from rainfall having a very-marked summer maximum (November to March) in the north, to an average rainfall occurring uniformly throughout the year in the south.

The present study examines changes in the assemblages of myxomycetes in an east-west direction from the middle of the semi-arid zone to near the greatest aridity in the arid zone, studying the effect of increasing mean aridity and increasing rainfall variability (rather than addressing any changes in the myxomycete assemblages in the north-south direction).

Materials and Methods

In the study area (Fig. 1) climate ranges from semi-arid with a 400 mm annual rainfall and a vegetation of open woodland with grasses underneath, to arid with 200 mm annual rainfall, and grassland vegetation with scrub covered sand-dune hills and a few tree-lined drainage channels.

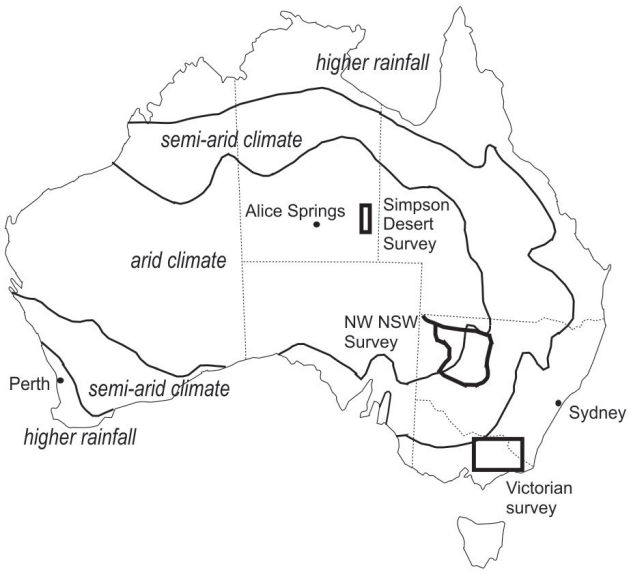

Fig. 1. Location of myxomycete surveys, and distribution of arid and semi-arid climate in Australia. Surveys: NW NSW (present study), Simpson Desert (Davidson et al., 2008), Victorian (Rosing et al. 2007).

Field collecting of visible myxomycete fruiting bodies is impractical because they would have to be targetted 1-2 weeks after major rainfall events, when many outback roads are closed or impassable. The alternative to field collections is to collect potential substrates and culture myxomycetes in moist chamber culture. Many different types of substrates contain myxomycete spores and microcysts, but the greatest number of myxomycete species are generally found on tree bark, so this survey concentrated on tree bark, but also included some herbivore dung, twigs on the ground, and one sample of lianas. The samples for this study were collected during dry weather in winter (11-19 August 2013), when myxomycetes are usually dormant.

The samples were collected along roads in northwest New South Wales that form a roughly square path, with sides about 300 km, and with corners near the towns Lake Cargelligo (400 mm annual rainfall), Bourke (400 mm annual rainfall), Tibooburra (200 mm annual rainfall) and Menindee (250 mm annual rainfall). The annual rainfall range over the study area is typical or comparable to the rainfall occurring in a large part of central Australia. To put this in context, except for a (generally) narrow coastal region, the wettest average

annual rainfalls in Australia are generally about 600 mm per year, and the driest in central Australia, about 150 mm.

Within the study area the mean maximum monthly temperatures range from 32–37°C in January and from 15–18°C in July, so bark is likely to be dry for much of the time between rainfall events, and the temperature is high enough for myxomycete growth during rain events from January to July.

For our study the summer-autumn rainfall for the prior six months had been slightly less than normal, and for most of the area rainfall had stopped more than one month prior to the sampling. The rainfall consisted of distinct rainfall events of 5–25 mm, separated by periods of 7 to 30 days with no rain. A similar rainfall pattern occurred along the length of the area surveyed.

Sample localities and types of sample material collected are listed in Appendix 1. Samples were collected in paper bags. For tree bark a single mixed sample was collected, with the sample consisting of small pieces of dead bark from living trees, about 1.5 m above ground level, from all sides of the tree trunk, and optimally from 3-4 trees of the same species. Tree bark samples were preferably taken within groves of trees so that, with greater shading, the drying of the bark would be slower. Dung samples were of weathered dung collected over an area of 4 m across; if the dung from more than one animal species was present, then all dung types were collected.

The samples were stored in a cool, dry place until processed. The moist culture method used was that described by Stephenson and Stempen (1994). Petri dishes 90 mm in diameter were used, with a single layer of filter paper placed on the bottom. Samples were placed on top of the filter paper with the weathered surface of the bark uppermost. Five replicate Petri dishes were prepared for each sample. The individual pieces of bark comprising the sample were cut or broken up into postage stamp sized fragments before they were put in a Petri dish. Fragments from the same piece of bark were divided among five Petri dishes so that, with the slight variations in growth conditions among the Petri dishes, there was a greater likelihood of obtaining at least one fruiting.

Petri dishes were half filled with distilled water, covered, left for 24 hours, and then excess water was poured off. Dishes were kept covered, but not sealed, at about 22°C with only reflected daylight. Each week dishes were inspected with a stereomicroscope at 7x magnification, and the mature fruiting bodies removed, dried, and glued to small piece of cardboard. The moist culture of the bark and twig samples continued for between 2-3 months, and the dung samples for 3 months. Most samples were then dried out, rewet and monitored for a month. After both periods of drying out, mature fruiting bodies were removed from the non-weathered base of the samples.

Identification of the dried fruiting bodies of myxomycetes was carried out using Martin and Alexopoulos (1969), Nannenga-Bremekamp (1991), Ing (1999), Stephenson (2003), Poulain et al. (2011), and the website *Discover Life* (2015) (www.discoverlife.org). Temporary microscope slides were made by soaking the material in alcohol and 5% KOH solution. Semipermanent microscope slide mounts of many species were made to study the stalk, peridium, capillitium, and inflated spores by soaking the fruiting body in alcohol, then in 5% KOH solution, in water, and then in 'Brite' mountant (a USA furniture polish used for liverwort slides), and covering with a cover slip. Semi-permanent mounts of members of the Stemonitaceae were made by blowing spores off the fruiting body and gluing the latter horizontally in the air space of a cavity slide. The cavity was covered with a cover slip, fastened with 'Scotch' tape. Two groups that produced smaller fruiting bodies (*Echinostelium* and small sessile members of the genus *Licea*) were largely ignored in the study because of the poor sampling when looking for mature fruiting bodies at 7x magnification and the difficulty of definite identification with the microscopes available. It was not possible to identify some fruiting bodies that were few in number, malformed, partly colonized by fungi, or without enough features for identification.

List of species identified

The species of myxomycetes identified in our north western NSW study are listed below (Table 1) with information on the localities where each species was found. New records for Australia are *Clastoderma pachypus and Comatricha anomala*, whereas likely new species are *Arcyria sp. H* and *Cribraria sp. A*.

The species listed herein as *Cribraria sp. A* is described below.

Sporangia generally in small groups, erect, 0.3-0.4 mm total height. *Stalk* 0.2-0.3 mm long, translucent and ranging from pale yellow to brown, paler towards the top, longitudinally grooved, diameter 25-30 µm near the base and 4-6 µm at the top, narrowing mainly at the top. *Sporocyst* spherical to slightly obovoid, 0.07-0.09 mm diameter. *Cup* 1/3 to 1/2 the height of the sporocyst, upper margin smooth with no threads projecting, no net seen, and all spores lost easily; cup overall grey, with a diameter when flattened of 0.07 mm, mainly translucent, but grey colouring on some radials and along the edge; when the cup is flattened to a circle there are no tears formed across the cup, consistent with the cup being pleated when containing spores. *Spores* in dark violet in mass, light grey in transmitted light, slightly irregular in outline, ornamentation is small, even and spinulose, diameter 6.5-7 µm. This species is similar to *Cribraria zonatispora* Lado, Mosquera & Beltrán-Tej and *Cribraria fragilis* Lado & Estrada in not having a net, but it does not have the unusual spores of either of these.

Table 1. The species of myxomycetes identified in the north west NSW study. For each species, information is provided on the localities where it was found. When the samples were not on bark, then the type of substrate is indicated by D for dung, L for lianas, and T for twigs on the ground.

Arcyria cinerea (Bull.) Pers., 60A, 60B, 64C, 71A, 74A [C].

Arcyria cf. *cinerea* 67B **D** (brick red, similar to *Arcyria* sp. of Eliasson & Lundqvist, 1979).

Arcyria insignis Kalchbr. & Cooke, 62B **L** [C].

Arcyria sp H, 62A, 64C, 65A, 67A, 70C, 71A, 72A (for a description see McHugh et al., 2003, and Davison et al., 2008).

Badhamia versicolor Lister, 60A [NA, E, J]

Badhamia macrocarpa (Ces.) Rostaf, 60A, 60B, 64B, 82A [C].

Badhamia melanospora Speq., 73A **D** [E, NA]

Badhamiopsis ainoae (Yamash.) T.E. Brooks & H. W. Keller, 64A, 66A, 70B, 71B, 83A, 84A [NA, E, J].

Calomyxa metalica (Berk.) Nieuwl., 61A, 62C, 64A, 64B, 75A, 77A, 78A, 81A, 82A, 83A, 84A, 84B [C].

Clastoderma pachypus Nann.-Bremek., 65A [E + NA].

Comatricha anomala Rammeloo, 70A, 78B, 86A [E].

Comatricha ellae Hark, 62A, 62C, 64A, 64B, 64C, 64D T, 65A, 67A, 71A, 71B, 72A, 73B, 75A, 76A, 78B, 79A, 82A, 84A, 86A [E].

Comatricha laxa Rostaf., 71B, 84A [C].

Comatricha pulchella (C. Bab.) Rostaf., 67A, 76A [C].

Cribraria confusa Nann.-Bremek. & Y. Yaman, 76A [C].

Cribraria minutissima Schwein., 67A [C].

Cribraria sp. A, 64C, see text for description.

Dianema corticatum Lister, 64B, 66A, 70B, 71A, 71B, 73B, 74A, 77A, 79A, 80A, 82A, 83A, 84A [NA, E, J].

Didymium cf. decipiens, 63A, 70B, 77A, 78B, 84B, dark spores 16-17 µm.

Didymium dubium Rostaf.,62B **L**, 62C, 64C, 70B, 70C, 71A, 71B, 73A **D**, 73B, 76C **T**, 78B, 79A, 81A [C].

Didymium clavus (Alb. & Schwein.) Rabenh., 60A, 60B [C].

Enerthenema papillatum (Pers.) Rostaf., 60C, 65A, 67A, 73B, 75A [C].

Fuligo cinerea (Schweinitz) Morgan, 73A kangaroo **D**, 82B kangaroo **D** [C].

Lamproderma scintillans (Berk. & Broome) Morgan, 76C **T** [C].

Licea biforis Morgan, 64C, 71A, 71B, 73B, 78B, 79A, 81A, 82A, 83A, 84A [C].

Licea kleistobolus G. W. Martin, 60A, 64A, 64C, 70B, 70C, 71B, 75A, 76A, 77A, 78B, 79A, 80A, 82A, 83A, 84B [C].

Licea scyphoides T. E. Brooks & H. W. Keller, 64A [NH].

Macbrideola argentea Nann.-Bremek. & Y. Yamam, 64B [C].

Macbrideola oblonga Pando & Lado, 61A, 62C, 64A, 64B, 64C, 66A, 70A, 70C, 71B, 73B, 744A, 78A, 78B, 82A, 83A, 84A, 84B [southern E].

Macbrideola synsporos (Alexop.) Alexop., 61A, 62C, 64B, 66A, 78B, 80A, 82A, 83A [mainly southern E].

Paradiacheopsis fimbriata G. Lister & Cran.) Hertel ex Nann.-Bremek., 65A, 72A, 76C **T**, 86A [C].

Paradiacheopsis rigida (Brândza) Nann.-Bremek., 60A, 64B, 64C, 67A, 74A. [Northern Hemisphere temperate].

Perichaena depressa Lib., 73A **D** rabbit & kangaroo, 64D **T** [C].

Perichaena pedata (Lister & G. Lister) G. Lister, 82B kangaroo **D** [C].

Perichaena vermicularis (Schwein.) Rostaf., 60A, 62C, 64A, 64C, 66A, 70A, 70B, 70C, 71A, 74A, 76A, 77A, 78B, 82A, 82B **D**, 84A [C].

Physarum cinereum (Batsch) Pers., 76C **T** [C].

Physarum decipiens M. A. Curtis, 60B, 61A, 63A, 64A, 64B, 64C, 66A, 70B, 70C, 71A, 71B, 74A, 75A, 78B, 79A, 80A, 83A, 84A, 84B [NH].

Physarum decipiens 'heaped eggs' (possibly a variety of this species, greener, heaped and egg shaped), 62A, 62C, 62B **L**, 64B, 64C.

Physarum leucophaeum Fr., 62C, 71A, 81A [C].

Physarum robustum (Lister) Nann.-Bremek., 60A, 61A, 62C, 64B, 64C, 66A, 70B, 70C, 71B, 75A, 79A, 82A [E].

Reticularia olivacea (Ehrenb.) Fr., 60A, 70A, 71A [NA, E].

Stemonitopsis amoena (Nann.-Bremek.) Nann.-Bremek., 62B **L**, 64D **T**, 71A, 74A [E].

Trichia contorta (Ditmar) Rostaf., 60A, 62A, 64C [C].

Comparison of surveys

When comparing surveys, there are three factors to consider: (1) whether species are common between surveys, (2) the abundance of each species and (3) whether each species is, or is not, cosmopolitan.

One way of analysing the significance of the presence of a species is to look at its world distribution. The primary division is between cosmopolitan and non-cosmopolitan species. A distribution is classified as cosmopolitan where the species are widespread and common. The cosmopolitan species are marked by C in Tables 1 and 2. A distribution is classified as non-cosmopolitan where the species is uncommon or appears to be restricted to certain regions of the world. Table 2 shows two measures of whether the species is non-cosmopolitan. A measure of the world abundance of each species is given by the number of world herbarium records reported on *Discover Life* (2015) (www.discoverlife.org). Cosmopolitan species are generally sufficiently common to have over 300 records worldwide. A measure of the concentration of the distribution is derived from the distribution of the points on the world map of *Discover Life* (2015) (www.discoverlife.org) for each species, (the map not enlarged as this changes the cell size). On the world map each point represents one or more records in that area, and a measure of the concentration of the species is given by the number of points within the nominated concentration area (given in the species list below), compared with the total number of points on the map. Abbreviations used for regions of the world are [E] for Europe; [NA] for North America; [J] for the Japanese region of Asia; and [NH] for Northern Hemisphere.

Table 2. Distribution of selected myxomycetes in the relatively dry (arid and semi-arid) and relatively wet areas of Australia.

For Australian distribution, numbers indicate the number of sites where species have been recorded.

*** Samples in herbarium collections, as given in Discover Life (2015) (www.discoverlife.org).**

**** This column includes the sites of the eastern Victorian survey.**

 # C, cosmopolitan; centres of species distribution: E, Europe; J, Japanese area of Asia; NA, North America; NH, Northern Hemisphere.

	Australia					World		
	arid and semi-arid areas			wetter areas				
	NW NSW, present study	Simpson Desert, Davison et al. (2008)	western arid and semi-arid	E Victoria, Rosing et al. (2007)	Australia wetter than semi-arid**	species distribution#	abundance	proportion in main area
	survey records	survey records	herbarium records*	survey records	herbarium records*		World herbarium records	World map cells with one or more records
Arcyria cinerea	5	1	3	3	17	C	6008	
Arcyria sp. H	8	1	1					
Badhamia macrocarpa	4				1	C	317	
Badhamiopsis ainoae	6					NA, E, J	123	16/18
Calomyxa metalica	12		1	1	3	C	365	
Comatricha anomala	3					E	102	6/6
Comatricha elegans		6	5		8	C	544	
Comatricha ellae	18		1		4	E	257	18/23
Comatricha laxa	2	9	2	2	11	C	947	
Comatricha pulchella	2		1		4	C	837	
Cribraria confusa	1		1	1	4	C	209	
Cribraria minutissima	1		1	1	11	C	176	
Dianema corticatum	13		1			NA, E, J	221	38/42
Didymium clavus	2				1	C	910	
Didymium cf. decipiens	5							
Didymium dubium	10				4	C	969	
Didymium squamulosum		1	1		15	C	4083	
Enerthenema papillatum	5			3	7	C	1495	
Licea biforis	10	4	2	1	4	C	346	
Licea kleistobolus	15	6	4	1	5	C	751	
Macbrideola oblonga	17	3	1			Southern E	181	8/12
Macbrideola synsporos	8			1		Southern E	82	10/13
Paradiacheopsis fimbriata	3	1	2	1	6	C	496	
Paradiacheopsis rigida	5					NHT	22	11/11
Perichaena vermicularis	15	1	3		5	C	1228	
Physarum decipiens	21	3	1			NH	678	57/60
Physarum leucophaeum	3		1		2	C	1573	
Physarum robustum	12		1			E	321	8/16
Reticularia olivacea	3				1	NA, E, J	197	25/29
Stemonitopsis amoena	2	2	1		1	E	176	13/19
Trichia contorta	3		2		3	C	1588	

Species distribution within the study area

Table 3 summarises the main results obtained for the 34 bark samples, excluding species found at only a single locality, and the one sample providing a single species (69A). A reasonable number of identified species was found in each sample, the samples had between one and 13 species, there was an average of 6.6 identified species per sample, and 12 samples had more than 7 identified species. A total of 43 species were recognized.

In this survey the abundant species are non-cosmopolitan, and the rarer species are cosmopolitan. Only about half of the species found in this survey are cosmopolitan indicating the composition of the assemblage is very unusual.

An important result from our survey is that no major change in the diversity of the myxomycete assemblages of was observed across an east-west traverse of the arid and semi-arid zones. Most species extended along the whole traverse without any change in the proportion of trees in which they are found or in the number of fruitings harvested from the sample. In areas of higher rainfall a slightly greater number of species occurred in only one sample (not shown in Table 3). The absence of significant change along traverse may be due to lower mean annual rainfall not having a major impact upon myxomycetes as they are only active after significant rainfall, and the temperature and different tree barks are similar when these organisms are active.

Bark Types

- Bark types with many species recorded, generally yielded most species common in this survey; that is most bark types gave very similar myxomycete species. However some myxomycete species were more restricted in occurrence - *Arcyria cinerea* was found only on 'box' and 'pepper' bark types, *Arcyria sp. H* was found only on 'box', 'mallee' and *Grevillea* bark types, and *Badhamiopsis ainoae* was found only on bark samples from *Acacia* and *Casuarina*).
- Samples of *Eucalyptus camaldulensis* (River Red Gum) were collected because this tree is found over much of eastern Australia, and has potential for determining the geographic extent of particular myxomycete species on a widespread single tree species. Unfortunately, it cannot be used for this purpose, as it proved difficult to obtain dead bark, and the bark obtained yielded few species (no species at one site and only two species at the other site).
- One sample (86A) of *Eucalyptus sideroxylon* (Red Ironbark) was collected (200 km southeast of the other samples) because the bark is very different from the other types collected, being very hard, with about 30% gum. This sample yielded only five species (all members of the Stemonitales). These species occur on the bark of other trees but the balance of the assemblage present is very different.
- The mallee Eucalyptus samples were collected because this tree type is very common in central and southern Australia. On these trees the bark is primarily alive at the surface ('gum' type), and the only dead bark that could be collected were small pieces caught up at branch junctions. For the three samples collected, the number of species per sample was low (4-5), but the species Comatricha anomala and Comatricha pulchella were unusual in the survey.
- The two samples of *Corymbia* (Bloodwood) had thick bark composed of very thin layers, but only two myxomycete species were obtained from one tree and one from the other.
- *Schinus molle* (Pepper tree), although exotic, is widely planted in country towns and around farm homesteads and water tanks, so it could be useful in future surveys. However, the bark yielded low numbers of myxomycete species per sample, and the assemblage was similar in composition to that on most native trees sampled.
- All bark samples were from angiosperms except for the gymnosperm *Callitris* (family Cupressaceae), which yielded an assemblage of bark myxomycetes very similar to that found on angiosperms, with no unusual species.
- Some bark samples were covered by discrete crystals or a thin layer of clay. The crystals are likely to be of salt. The clay layer formed on trees that were in narrow valleys; deposited by water when the tree had been partly submerged. These coverings do not seem to have any effect on the myxomycete growth or the production of fruiting bodies.

In addition to samples of tree bark, moist chamber cultures were prepared with five dung samples, two twig samples and one sample of lianas. The number of identified species found per sample was small, so these substrates are less useful in determining the nature of the myxomycete assemblage than bark samples. The species found on dung were not exceptional, with all the dung species being already known on dung elsewhere in the world (Eliasson & Keller, 1999).

The distribution data from our survey gives several instances where unusual myxomycetes were recorded from adjacent trees at a particular site. *Badhamia macrocarpa* was found at 60A & B, *Didymium clavus* at 860A & B, and *Physarum decipiens* 'heaped eggs' at 62A, B & C and 64B & C. This distribution is consistent with spore clouds/species blooms promoting local concentrations of a species or forms over distances of 100 m or so. This is sometimes observed in field collecting in temperate Australian rain forests, where a single species is very common on many surfaces in a very local area.

The moist chamber method provides quantitative information about species occurrence, variability and productivity, as the sample size put in the dishes is reasonably constant. (In contrast, in the field collection method, samples are related to an unknown amount of substrate material). The number of fruiting bodies at each locality (Table 1) gives a measure of the variability of the fruiting crop among samples. An interesting feature of Table 1 is that the average number of fruitings of a species per sample is generally between 10 and 20. If this was random, then this narrow range seems a little unusual.

Table 3. Myxomycetes recorded from bark samples (from more than one sample). The numbers in the body of the table give an estimate of the number of fruitings found. Tree types are as follows: A, *Acacia*; B, *Eucalyptus* of the box type; C, *Callitris;* Ca, *Casuarina*; Co, *Corymbia*; E, *Exocarpos*; G, *Grevillea*; Ma, *Eucalyptus* of the mallee type; My, *Myoporum*; P, *Schinus*; R, *Eucalyptus camaldulensis*; S, *Eucalyptus sideroxylon.*

sample number	60A	60B	61A	62A	62C	63A	64A	64B	64C	65A	66A	67A	70A	70B	70C	71A	71B	72A	73B	74A	75A	76A	77A	78A	78B	79A	80A	81A	82A	83A	84A	84B	86A	#	#	average #
tree type	B	P	My	Ma	C	My	A	C	B	G	A	Ma	Ma	A	B	B	A	Co	B	B	A	G	B	R	G	B	B	P	C	Ca	Ca	E	S	fruits	sites	fruits/site
Arcyria cinerea	9	1							22							12				39														83	5	17
Arcyria sp. H				118					6	37		5			6	1		71				22												266	8	33
Badhamia macrocarpa	6	33						5																					13					57	4	14
Badhamiopsis ainoae							30				4			7			20													19	39			119	6	20
Calomyxa metalica			8		1		21	1													9		2	1				3	38	12	16	4		116	12	10
Comatricha anomala													24												7								4	35	3	12
Comatricha ellae				21	8		11	20	4	200		26				10	40	70	7		12	20			2	4			6		1		150	612	18	34
Comatricha laxa																	2														1			3	2	2
Comatricha pulchella												12										10												22	2	11
Dianema corticatum								2			9			3		2	1		2	5			2			1	17		5	2	4			55	13	4
Didymium clavus	1	49																																50	2	25
Didymium cf. decipiens						14								1									15		12							1		43	5	9
Didymium dubium					17				2					34	43	2	9		30						12	13		31						193	10	19
Enerthenema papillatum					160					400		10							69		3													642	5	128
Licea biforis									100							30	1		90						21	20		72	80	46	3			463	10	46
Licea kleistobolus	41						1		53					3	2		4				11	3	20		2	5	1		10	3		2		161	15	11
Macbrideola oblonga			3		40		4	10	2		2		1		1		6		2	20				115	20				18	5	4	1		254	17	15
Macbrideola synsporos			1		1			2			1														2		2		3	2				14	8	2
Paradiacheopsis fimbriata										32								1															20	53	3	18
Paradiacheopsis rigida	30							20	10			4								8														72	5	14
Perichaena vermicularis	2				1		9		1		5		14	2	12	76				100		1	1		2				12		17			255	15	17
Physarum decipiens		34	2	70	65	41	3	37	8		7			1	23	15	9			19	4				14	2	10			2	20	51		437	21	21
Physarum leucophaeum					28											100												3						131	3	44
Physarum robustum	192		20		2			67	70		31			21	12		11				7					48			80					561	12	47
Reticularia olivacea	13												1			9																		23	3	8
Stemonitopsis amoena																1				20														21	2	11
Trichia contorta	7			2					20																									29	3	10
number of fruits	301	117	34	211	323	55	79	164	298	669	59	57	40	72	99	258	103	142	200	211	46	56	40	116	94	93	30	109	265	91	105	59	174			
number of species	9	4	5	4	10	2	8	10	13	4	7	5	4	8	7	12	10	3	7	7	6	7	5	3	10	7	4	4	10	9	10	4	4			

Discussion

The main work complementary to the present survey is Davison et al. (2008) for the northern Simpson Desert, 830 km northwest of our study area (Fig. 1). This area has a mean average rainfall of 210 mm, mainly falling during the summer and is similar to the area at the NW limit of our survey, although it is more concentrated in summer and its mean temperature is 2-3 degrees hotter over summer. Davison et al. (2008) sampled 24 localities, obtaining 84 records of 35 species. Excluding *Echinostelium* and most species of *Licea* (not identified in the present study), they had 48 records from 20 sites, with an average of 2.4 records per site. The assemblages recorded in the two surveys are similar as the abundant species are similar, and many of the non-cosmopolitan species of our NSW survey are found in the Simpson Desert. Five of their six species with over three records were all found in our NSW survey, and 7 other species of 1-2 records were also found (see Table 2). Eight of their species were not found in the present survey.

Herbarium collections provide another data set of Australian arid and semi-arid myxomycete sites. Australian herbarium collections are reported in AVH (2015), and both Australian and overseas collections in *Discover Life* (2015) (www.discoverlife.org). As overseas collections are a significant proportion of the known Australian collections, data from the Discover Life (2015) website was used. Collections in these databases come from both bark and other substrates. I have counted on maps in *Discover Life* (2015) (www.discoverlife.org) those sites within the arid and semi-arid area of Australia that are not sites of the Davison et al. (2008) survey. As they are all on, or to the west of, the main highway through Alice Springs in Central Australia they are in the western two thirds of the arid and semi-arid Australia. Table 2 shows the species list largely from Table 1 of this paper, (but with the addition of Comatricha elegans and Didymium squamulosum which were found on both the other surveys), with the number of sites known for each species for the three arid and semi-arid data sets. Many of the species are clearly widespread throughout much of the arid and semi-arid area of Australia, and the data in the table are consistent with there being one assemblage that characteristically occurs over the arid and semi-arid area. However, the information available is very sparse over most of the area.

An important question is the relationship between the assemblage characteristic of the arid and semi-arid zones and those of the adjacent higher rainfall zones. The comparison is difficult to make because all moist chamber culture bark studies in the higher rainfall areas of NSW and Victoria (published and unpublished) have given poor results with few species found per sample. The only published survey of a temperate tree-bark moist chamber assemblages, for a reasonable number of localities (12 localities), is that of Rosing et al. (2007) for eastern Victoria (Fig. 1), with the samples collected in late March. This area (lat 36°04'–37°42'S, long 145°20'–149°21'E) is 400 km due south of the southeast end of our main traverse (sample 60), and the average annual rainfall ranges from 600 to 1500 mm/year. Rosing et al. (2007) looked at the bark substrate at 12 widely scattered localities with an average of 5 species per locality and a total of 36 species. The survey did not define which species were abundant because the number of records is too small. Ten species found in the Victorian survey were found in our NSW survey (Table 2). However, with one exception these 10 species are cosmopolitan and their presence is unremarkable. The Victorian survey did not find most of the more abundant species nor most of the non-cosmopolitan species of our NSW survey.

When the records for arid and semi-arid Australia are compared with the remaining wetter part of Australia (Table 2) using records of herbarium collections reported in *Discover Life* (2015) (www.discoverlife.org), excluding the arid and semi-aid zones, there is confirmation of very different assemblages. The abundant species in the wetter area (*Arcyria cinerea, Comatricha laxa, Cribraria minutissima, Didymium squamulosum*) are not generally abundant in arid and semi-arid Australia, and the non-cosmopolitan species are absent or not abundant indicating the assemblages are very different.

The boundary zone between the assemblages characteristic of the arid and semi-arid and the wetter areas was not determined by our survey. However, there is no reason to expect the boundary to be sharp. Characteristic species of the arid and semi-arid assemblage (e.g., *Arcyria sp. H, Badhamiopsis ainoae, Dianema corticatum, Didymium cf. decipiens, Macbrideola oblonga* and *Physarum robustum*) have a range that extends to the east margin of the survey, so these species must extend past the middle of the semi-arid zone. The cosmopolitan species *Didymium clavus, Cribraria minutissima* and *Macbrideola argenta* were found only on the eastern margin of the survey area, so half way across the semi-arid zone may be the western margin of their range. These observations are consistent with the middle of the assemblage boundary being east of the survey, and probably near the outer margin of the semi-arid zone.

Of the non-cosmopolitan species found in this survey, six are found overseas, mainly in Europe (*Physarum robustum, Macbrideola oblonga, Macbrideola synsporos, Stemonitopsis amoena, Comatricha anomala* and *Comatricha ellae*). None appears to be mainly distributed in North America, so there is a bias to European species. This is attributed to the area generally having winter rain. Superimposed on this there is a tendency for the species to be associated with southern rather than northern parts of both North America and Europe. This is strongly shown in the distribution of *Macbrideola oblonga, Macbrideola synsporos* and *Comatricha anomala*, and weakly shown in *Badhamiopsis ainoae and Dianema corticatum*. This is consistent with the latitude of the survey area (29-33°S) being equivalent to the southern boundary of the United States, and to the south of the southern margin of Western Europe. In summary, the bark assemblage is made up of about half cosmopolitan species, with the other half consisting of species with a distribution in the temperate Northern Hemisphere, or Europe, or southern Europe and the southern United States.

The survey area is in the arid and semi-arid climate classification (http://en.wikipedia.org/wiki/Köppen_climate_classification) of Köppen. It is near the boundary between the hot semi-arid climate (BSh) and the cold semi-arid climate (BSk), and near the boundary between dominant summer rain and dominant winter rain. Similar climates are found elsewhere around the world at a similar latitude and low altitude, mainly in South Africa, NW Argentina, near the Mexico/United States border, and in discontinuous areas between Morocco along the northern margin of Africa to Pakistan. Unfortunately, similar tree-bark moist chamber culture surveys are not yet known for most of these areas.

Overseas, the diversity of myxomycetes in some arid and semi-arid areas is due in part to species found on cacti and other succulents (Lado et al., 2011). Australia has no endemic cacti but has a reasonable proportion of endemic succulents (Kapitany, 2007). These are widely distributed and some are in the arid and semi-arid zones. However, because of their small size and insignificant water-gathering ability, they are likely to be poor substrates for myxomycetes. No suitable succulents were observed in the areas surveyed.

Conclusions

This study used 34 samples to find which myxomycetes species were present in tree bark in arid and semi-arid NSW. The species present and their abundance does not significantly change across the area sampled, and for samples with a reasonable number of myxomycete species there was generally little difference between the tree species. Other bark substrate surveys in arid and semi-arid Australia give a similar species list and abundance. Surveys of bark substrate in wetter areas of Australia give a different species pattern. Generally the more common species in the arid and the semi-arid areas are absent or of low abundance in the wetter areas; they are not cosmopolitan species, and have a world centre of distribution in Europe, or temperate Northern Hemisphere. Generally the more common species in the wetter areas are not common in the arid and semi-arid areas, and these are cosmopolitan species.

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Appendix 1. Sample locations and host material for Myxomycete records in North West NSW

For each sample site (numbers in bold), the following information is listed: sample number, location, latitude, longitude and altitude above sea level. Individual samples at a site are indicated by A, B etc., with sample type (whether bark, dung, twigs or lianas), and the name of the tree, or type of animal producing the dung. The actual field collection number is the given number preceded by 8, so that sample 60A refers to a field sample number of 860A. NP refers to National Park and NR to Nature Reserve. Of the trees only *Schinus molle* is exotic; *Callitris* is the only gymnosperm.

60 Yathong NR, 32° 39.0'S, 145° 39.9'E, 199 m.
60A bark, *Eucalyptus intertexta*, Red box.
60B bark, *Schinus molle*, Pepper tree.

61 Yathong NR, 32° 38.8'S, 145° 39.6'E, 205 m.
61A bark, *Myoporum platycarpum*, Sugarwood.

62 Yathong NR, 32 38.7'S, 145 39.2'E, 344 m.
62A bark, *Eucalyptus socialis*, Red mallee.
62B stem, *Pandorea pandorana*, Wonga vine.
62C bark, *Callitris columellaris*, White cypress pine.

63 Mount Grenfell Historic Site, 31° 17.8'S, 145° 18.8'E, 285 m.
63A bark, *Myoporum platycarpum*, Sugarwood.

64 Mount Grenfell Historic Site, 31° 18.1'S, 145° 18.4'E, 247 m.
64A bark, *Acacia*.
64B bark *Callitris*.
64C bark *Eucalyptus*, box type bark.
64D twigs under *Eucalyptus*.

65 Cobar to Bourke road, 31° 25.2'S, 145° 20.4'E, 199 m.
65A bark, *Grevillea striata*, Beefwood.

66 Gunbooka NP, 30° 38.4'S, 145° 46.1'E, 174 m.
66A bark, *Acacia doratoxylon*, Currawang.

67 Gunbooka NP, 30° 38.4'S, 145° 45.8'E, 171 m.
67A bark, *Eucalyptus socialis*, Red mallee,
67B, dung, kangaroo and goat.

68 Gunbooka NP, 30° 35.1'S, 145° 41.5'E, 214 m.
68A bark, *Corymbia tumescens*, Western bloodwood.

69 Bourke wharf, 30° 05.3'S, 145° 56.1'E, 107 m.
69A bark, *Eucalyptus camaldulensis*, River red gum.

70 30 km E of Wanaaring, 29° 50.2'S, 144° 36.2'E, 106 m.
70A bark, *Eucalyptus socialis*, Red mallee.
70B bark, *Acacia*, tall, rough bark.
70C bark, *Eucalyptus microtheca*, Coolibah.

71 Sturt NP, 29° 18.4'S, 142° 09.3'E, 115 m.
71A bark, *Eucalytus microtheca*, Coolibah, box type bark.
71B bark, *Acacia*, tall with rough zigzag bark.

72 Sturt NP, 29° 25.0'S, 142° 00.0'E, 206 m.
72A bark, *Corymbia terminalis*, bloodwood.

73 Sturt NP, 29° 05.2'S, 141° 13.1'E, 134 m.

73A dung, rabbit, kangaroo.

73B bark, *Eucalyptus coolabah*, Coolabah, box type bark.

74 Road from White Cliffs township to Paroo-Darling NP, 30° 50.5'S, 143° 16.9'E, 124 m.

74A bark, *Eucalyptus microtheca*, Coolibah box type bark.

75 Paroo-Darling NP, 30° 40.0'S, 143° 35.3'E, 79 m.

75A bark, *Acacia*.

75B dung, kangaroo.

76 Paroo-Darling NP, 30° 43.0'S, 143° 30.4'E, 110 m.

76A bark, *Grevillea striata*, Beefwood.

76B twigs of shrubs.

77 Mandalay Homestead to Wilcania road, 31° 12.0'S, 143° 28.9'E, 80 m.

77A bark, *Eucalyptus largiflorens*, Black box.

78 Wilcania town, 31° 33.6'S, 143° 22.6'E, 71 m.

78A bark, *Eucalyptus camaldulensis*, River red gum.

78B bark, *Grevillia robusta*, Silky oak.

79 Wilcania to Menindee Road, 32° 06.9'S, 142° 43.1'E, 73 m.

79A bark, *Eucalyptus largiflorens*, Black box.

80 Near Menindee town, 32° 18.8'S 142° 30.5'E 71 m.

80A bark, *Eucalyptus largiflorens*, Black box.

81 Menindee township, 32° 23.7'S, 142 24.9'E, 62 m.

81A bark, *Schinus molle*, Pepper tree.

82 Menindee to Ivanhoe Road, 32° 27.7'S, 142° 45.0'E, 68 m.

82A bark, *Callitris*, Callitris pine.

82B dung, kangaroo.

83 Menindee to Ivanhoe Road, 32° 28.6'S, 142° 49.6'E, 74 m.

83A bark, *Casuarina cristata*, belah.

84 Ivanhoe to Trida Road, 32° 53.8'S, 144° 39.8'E, 96 m.

84A bark, *Casuarina cristata*, Belah.

84B bark, *Exocarpos aphyllus*, Leafless ballart.

86 Weddin Mountains NP, 33° 54.2'S. 147° 57.8'E, 471 m.

86A bark, *Eucalyptus sideroxylon*, Red Ironbark.