CHANGES IN THE ASSEMBLAGE OF MOSSES ON LIMESTONES IN SOUTH-EASTERN AUSTRALIA - SOME IMPLICATIONS FOR THE MANAGEMENT OF KARST SYSTEMS

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We have been studying the mosses and liverworts which grow on limestones in south eastern Australia and have found that we can recognise a limestone (calcareous) substrate by the combination of mosses and liverworts which it supports. However, some recent work, in which we were able to compare a 1906 collection of mosses from Yarrangobilly Caves with our recent 1993 collection, showed that there are many more species of mosses present on limestone at Yarrangobilly in 1993 than there were in 1906. The changes in composition of the moss assemblage appear to have implications for the management of karst systems.

Mosses and their relatives

Mosses, liverworts and hornworts together make up the three classes of the Division Bryophyta of the Plant Kingdom. Mosses have well developed stems and leaves, and produce spores in capsules at the top of wiry stalks. Liverworts can be thallose, with an undifferentiated plant body, but they can also be leafy, with complex arrangements of stems and leaves. Spores are produced in globular capsules at the top of pale, fragile stalks. Hornworts, the third group, have thallose plant bodies, somewhat similar to those of thallose liverworts, but spores are produced in elongated green capsules. Mosses, liverworts and hornworts all have the extraordinary ability to regrow from just a few cells of stems, leaves or capsules.

In the northern hemisphere, the vegetation of limestone is unique, and includes many species of mosses, liverworts, ferns and flowering plants which are found on no other rock substrate. In contrast, the mosses and liverworts which we find on Australian limestones include very few species which occur only on limestone. However, we have found that limestones can be identified by a characteristic assemblage of mosses and liverworts. It is dominated by short, upright mosses from two families (Pottiaceae and Bryaceae), and by thallose liverworts from the order Marchantiales. Certain key species are always present (*Didymodon torquatus, Gigaspermum repens, Fissidens vittatus, Bryum dichotomum* and/or *Bryum pachytheca*. We also find many species which are more usually associated with arid and semi-arid areas of south-central Australia.

Mosses at Yarrangobilly

In 1906, the Reverend W.W.Watts, an eminent Australian bryologist, collected mosses at Yarrangobilly Caves in the Southern Tablelands of New South Wales. He sent his specimens to Brotherus, a German bryologist, and, in 1912, Brotherus and Watts published a list of species which occurred in the vicinity of Yarrangobilly Caves. Watts was a great collector, and he had an extraordinary eye for detail, collecting and describing many of the type specimens of Australian mosses and liverworts. His collections are now housed at the National Herbarium of N.S.W. in Sydney, and we have been able to compare his 1906 collections with our 1993 collections. There are many more moss species growing at Yarrangobilly now than there were in 1906.

Comparisons of two collections:

	Watts 1906	Downing, Selkirk, Oldfield 1993
Species - Total Number	95	124
Number on limestone	62	89
Short, erect mosses	38	60
Creeping mosses	24	29
Pottiaceae	9	22
Bryaceae	10	16
Key Species:		
Didymodon torquatus	Present	Present
Gigaspermum repens	Absent	Present
Fissidens vittatus	Absent	Present
Bryum pachytheca	Absent	Present
Bryum dichotomum	Absent	Present
Arid Zone species	Few	Many

Watts' collection does not include all the elements which comprise the characteristic assemblage of mosses which we now find on all south-eastern Australian limestones, including Yarrangobilly. It appears that many of the species have arrived at Yarrangobilly since 1906. Their introduction can probably be attributed to disturbance resulting from European development.

Introduced mosses at Yarrangobilly

For new introductions to be successful, there are three essential elements: firstly, there must be a suitable substrate for colonisation, secondly a source of propagules, and thirdly, a means of transport.

Tourist development at Yarrangobilly began in 1879, and since then, extensive building programs have taken place, including the construction of paths, roads, gardens, farms, picnic areas and lookouts. The thermal pool was built in 1897. These activities, of necessity, result in areas of ground being laid bare for periods of time, and bare ground is an ideal substrate for colonisation by mosses and liverworts. The species new to Yarrangobilly can be grouped in a way that gives some insight into possible origins.

Cosmopolitan species are species that have a world wide distribution, and introduced species are those which are not native to Australia (weeds). At Yarrangobilly, they can be found, predictably, in high usage areas, such as paths and roadways, the areas adjacent to paths and roadways, picnic areas, on or adjacent to concrete or cement, on mortar in old brick work, round buildings, in gardens, in the vicinity of the Thermal Pool and in the vicinity of the old farm. They would have been introduced on the wheels of vehicles, on the hoofs and hide of stock, on boots and shoes, on building materials and garden plants.

In our previous work, we have found that the presence of sheep and cattle on calcareous substrates seems to increase the number of introduced and cosmopolitan species. For many years, sheep and cattle were moved from the western plains to alpine pastures for summer grazing. From National Parks and Wildlife Service publications, it is estimated that in the 1954-55 season alone, 40,000 sheep, and 1500 head of cattle were moved every year through the Yarrangobilly Valley to the high plains. We suspect that some species of moss which are now abundant at Yarrangobilly were introduced by stock movements.

Watts recorded relatively few epiphytic (plants which grow on other plants) mosses at Yarrangobilly. Smooth barked Eucalypts shed their bark regularly, making it almost impossible for mosses to colonise anything other than the short stockings of permanent bark at the base of the trunk. In eastern Australia, epiphytic mosses are mostly found on the rough bark of rainforest trees, and, with the exception of *Acacia melanoxylon* (Black Wattle), rainforest trees are not part of the natural vegetation at Yarrangobilly. However, we recorded numerous species not listed by Watts, mostly growing on the bark of exotic trees which have been planted at Yarrangobilly. They may have arrived as spores or plants (or fragments of plants) on nursery trees planted at Yarrangobilly and they may also have been transported by wind. Some of these recently arrived epiphytic mosses are now also quite common on limestone.

Watts wrote: **"**Close round the Springs, in swampy ground, I was rewarded with many treasures. This locality was richest in new species." Construction of the thermal pool and drainage of the adjacent areas have eliminated the swamp and Watts' treasures are no longer present. There are still some interesting and unusual mosses which grow under water and along stream banks of the Yarrangobilly River. However, sections of streams which run into the Yarrangobilly River are now so overgrown with exotic weeds that light is too dim for aquatic and stream bank mosses to grow.

Probably the largest group of newly arrived species of mosses at Yarrangobilly are those which form part of microphytic soil crusts on the calcareous soils of the arid and semi-arid zones of southern Australia. These crusts consist of complex combinations of cyanobacteria (blue-green algae), algae, lichens, mosses and liverworts, usually only a few millimetres high, and they are vital in minimising soil erosion from wind and water. Some of these species probably were transported on the hoofs of sheep and cattle, but we consider **dust storms** to be the most likely means of dispersal. Dust storms have occurred in Australia for at least the last 2 million years, but there is evidence to show that changing land use following European settlement has significantly accelerated the loss of soils from arid and semi-arid areas. In glasshouse trials, we have found that in only 8 weeks, it is possible to grow a complete cover of mosses and liverworts from propagules (spores and tiny fragments) present in sieved calcareous soils. The speed with which arid zone species are able to colonise bare ground must be significant in their ability to colonise eastern Australian limestones which have a much higher rainfall than their place of origin.

Recommendations for moss-friendly management

There are a number of recommendations which we would propose for the development and management of karst systems. We have commented on the ease with which bryophytes colonise bare soil, and our suggestions cover activities which removes existing natural vegetation leaving bare soil and rock. These comments refer specifically to the isolated, upland karst systems of south-eastern Australia, but should be considered elsewhere in development of new karst areas.

1. All buildings, wherever possible, should be constructed away from karst areas.

2. Construction of roads and paths should be kept an absolute minimum. If funds permit, build raised walkways.

3. Wherever possible, roads and tracks in karst areas should be constructed of limestone rock. At Jenolan, shale from the Six Foot Track used over limestone has

changed the bryophyte assemblage of the limestone substrate.

4. Stock (sheep and cattle) must be excluded.

5. Retain natural vegetation wherever possible, landscape with local native plant species and avoid planting exotic trees and shrubs. Implement a bushland regeneration program to remove existing weed species.

6. Avoid any changes to natural water features, such as streams, pools, swamps, bogs and heathland. Revegetate stream banks with native plants to allow light to reach watercourses.

In conclusion, we can sum up by noting a significant increase in the number of species of mosses on south-eastern Australian limestones in the last hundred years. Most of these introductions can probably be attributed to changing land use following European settlement, together with the development of tourist karst areas. It is probably too late to implement many of our suggestions at most of the tourist karst systems in south-eastern Australia but they may prove useful in the development of any new tourist areas.and to minimise further introduction of non-local species to those areas already developed. Our recommendations should also prove useful in the management of introduced species of flowering plants.

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