Spanish Moss (*Tillandsia usneoides*): An Environmental Weed

A Preliminary Assessment in Northern Sydney

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Front cover: A recently dead Turpentine covered in Spanish Moss

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SUMMARY

Spanish Moss is likely to be a serious weed in plant communities in which Turpentine, Lilly Pilly, Brush Box and Cheese Tree are a major component. Locally this includes the critically endangered Sydney Turpentine-Ironbark Forest and Blue Gum High Forest as well as Sydney Enriched Sandstone Moist Forest. On the north coast it includes Northern Turpentine-Brush Box Wet Forest.

Threats to ecosystems include causing the death of individual trees by reducing photosynthesis but also include subtle effects such as altered water and nutrient cycles, changed predator prey interactions, habitat alteration, moderation of the microclimate and transformed fire regimes. Changes such as these are one of the greatest conservation threats to biodiversity in Australia.

Spanish Moss can grow almost anywhere, but during our survey it was obvious it flourished on some tree species and not others. Our observations indicate that the leachate from the host, or epiphytic species such as lichens and fungi, may be a determining factor for Spanish Moss success. Spanish Moss was recorded on trees from 32 plant families and 65% of records were from the Myrtaceae (Myrtle) family where Turpentine and Brush Box dominated recordings. Of all the Eucalyptus in the northern suburbs only one, Red Mahogany, was recorded repeatedly carrying substantial amounts of Spanish Moss.

Festoons commonly occurred in the middle layer of the support plants (60%) and almost 90% were out of easy reach. Branches were the most common support (56%) followed by leaves, but only 12 host species (26%) were involved, primarily Turpentines. Festoons were mostly 0.5 to 2 m long but some extended over 3 m. Sparse infestations were the norm (48%) but most individual festoons were dense.

Dispersal rate appears to have been slow with people and animals the main dispersal agents over long distances, but many observations indicate that the spread, density and size of festoons is increasing exponentially. It is no longer a sleeper weed.

We found no mention of an obvious biological control. Overseas examples of control include hand removal and spraying with potassium or sodium bicarbonate or copper sulphate.

Spanish Moss has been underestimated as a threat. We recommend that it be added to the next iteration of the Greater Sydney Regional Strategic Weed Management Plan, not be distributed or sold, and be added as a separate threat to Sydney Turpentine-Ironbark Forest in the Sydney Basin Bioregion.

Widespread education about its potentially disastrous impact on some bushland communities and urban forests is urgently needed through gardeners, horticulturalists, bushland managers and professional organisations.

Also, research is urgently needed into the ecology of Spanish Moss, why it flourishes on some trees and not others, the ecological consequences of its presence as well as control methods suitable to Australian ecosystems and conditions.

INTRODUCTION

In recent years STEP has become increasingly concerned about the potential impact of Spanish Moss on our bushland and so in December 2023 we asked members to send us details of any Spanish Moss growing on trees (71).

Most notifications of infestations of Spanish Moss were between the Parramatta River/Sydney Harbour and Cowan, but we were also notified of infestations near Lake Macquarie and in the Dulwich Hill area. Other observations were fortuitous as we travelled in the area. Most observations were of street trees and gardens viewable from the street.

In the study area:

- altitude ranged from 215 m asl at Berowra Heights to 35 m asl at Dulwich Hill (59);
- average annual rainfall is approximately 1 200 mm; and
- mean temperature in summer ranges from approximately 18.5 to 26°C and in winter ranges from approximately 8 to 16.5°C (11).

Additional environmental information may be found on the Atlas of Living Australia for each individual record (3).

WHAT IS SPANISH MOSS?

Spanish Moss (*Tillandsia usneoides* (L.) L.) is also commonly known as Old Man's Beard but numerous other names occur around the world. *Tillandsia* species are commonly called air plants and the specific name *usneoides* means it looks like the lichen *Usnea* (67).

It is a perennial monocotyledon in the pineapple family Bromeliaceae (50) that grows abundantly from the Southern United States to the cooler regions of Argentina and Chile (58). It grows from sea level to about 3 000 m and hence tolerates a huge range of temperatures and annual rainfall (28). It grows in spring and summer in areas that have a summer temperature of over 20°C and a winter temperature of over 15°C, but it will tolerate winter temperature of –5.5°C (62). Rainfall ranges from a maximum of 1 905 mm to 1 016 mm (62).

Spanish Moss is an epiphyte that forms hanging festoons up to 8 m long (58, 63). As it only has true roots on young seedlings (28, 58) it generally loops over branches or catches in cracks and crevices in bark to start new festoons. The festoons are made up of numerous shorter plants twisting around and overlapping each other (28). Some native species also hang from branches and should not be confused with Spanish Moss (see p 25).

It grows slowly, is not allelopathic nor drought tolerant. It has low fertility requirements, is a medium moisture user, requires a pH of 6 to 6.9, has no salinity tolerance and is shade tolerant (62).

The small green flower is present from spring to autumn (63) and in this survey it was recorded from early November to late December (Fig 1). The fruit is a capsule up to 25 mm long (50) but we failed to find any mature fruit from November 2023 to June 2024. The flower rarely successfully self-pollinates (28). The seed is up to 3 mm long (544 310 seeds/kg) is uncommon and is produced in autumn and winter (62, 63). Seeds have feathery parachutes that enables them to float like dandelion seed (25). Seeds have no seed dormancy and can spread up to approximately 250 m away from the nearest Spanish Moss but spread is not rapid under normal conditions (28).

The surface of Spanish Moss plants is covered with tiny, grey scales (trichomes) that trap water and nutrients (Fig 2) which then move by capillary action on the outside of the plant (36). Vascular transport is unimportant (32). Rain, dew and fog are more important than relative humidity (28, 44). Water loss is reduced by crassulacean acid metabolism photosynthesis (42) that allows gas exchange at night (67). In the Southern United States, Spanish Moss is often found by ponds as clearing, frequent fires and barriers of dense pines prevent growth elsewhere (28). It generally grows best in high light conditions (28, 42, 44).

An unreferenced website (18) states that Spanish Moss can grow up to 10 to 20 cm each year.

In the Southern United States, Spanish Moss seems to show preferences for Southern Live Oak (*Quercus virginiana*) and Bald Cypress (*Taxodium distichum*) (67).

Many factors contribute to the success or failure of Spanish Moss on support plants. These include light intensity and temperature at various levels of the support plant, wind turbulence and relative humidity within the canopy, rainfall, fog, bark type, bark stability, water-holding capacity of the bark, tree size, the non-vascular epiphyte ecosystem on the bark and leaves and whether the tree and branches are alive or dead (12, 28, 44, 53).

Fig 1 Spanish Moss flower

Fig 2 Spanish Moss showing individual long thin strands and the scaly strand surface

Fig 3 The pattern of rain falling through the canopy and down the host's branches and trunk will change in areas of dense infestation – this will affect soil moisture content and distribution

The importance of several factors remains controversial, e.g. light intensity (28, 44), leachates from host trees (13, 35, 53) and the importance of the non-vascular epiphyte communities (12).

The pattern of throughfall, stemflow and leachate changes with infestation (13, 28, 53), particularly the ratio between ammonium and nitrate (29). See Fig 3.

Note: **Throughfall** is the portion of precipitation that falls through, or drips from, the canopy (52), whilst **stemflow** is the portion of the precipitation that drains from outlying leaves and branches and is channelled to the trunk (40, 52).

In its natural habitat Spanish Moss provides nesting material, nesting and resting sites for birds and bats (28, 60, 64, 65) and it also supports a wide range of invertebrate species (9).

METHOD

Location was recorded as suburb, street and coordinates. Family, scientific name and common name of the support trees were recorded where possible, but some introduced trees and shrubs were not differentiated into species and cultivar. Many introduced gymnosperms were only identified to family. The number of support trees was recorded but data about abundance, festoon thickness, location on the support plant, attachment height, length of longest festoon and support part was collected in classes, except for the measurement of spectacularly long festoons.

General notes were taken including information about nearest infested trees and those that remained free of Spanish Moss.

Many of the worst infestations were added to iNaturalist and hence the Atlas of Living Australia under the name, persepolis22 (3).

The age of major infestations at Mt Kuring-Gai, Wahroonga, Pennant Hills, West Pymble, Turramurra and Gordon was estimated by aerial photograph interpretation (55), assuming Spanish Moss was introduced at early garden development, verbal recollections and written records. Trove was briefly searched for early mentions of Spanish Moss and *Tillandsia usneoides*.

RESULTS

Support plants

Infestations were recorded in 294 support plants from 32 families and at least 76 deciduous and evergreen species (see Table 1).

Support plants were mostly dicotyledons and eudicots (woody flowering plants) (70), but magnoliids (magnolias) and the two tall monocot families (herbaceous flowering plants) Asparagaceae and Zingiberaceae were also recorded. Four families of gymnosperms (cone-bearing trees): Araucariaceae, Cupressaceae, Pinaceae and Podocarpaceae made up 13% of the families recorded.

Myrtaceae (the Myrtle family) dominated recordings with approximately 65% of support plants. The next most common families were Rosaceae, Rose family (4%), Proteaceae, Grevillea family (3%), Sapindaceae, Maple family (3%) and Cunoniaceae, Coachwood family. Cupressaceae, Cypress like trees, and Elaeocarpaceae, Blueberry Ash, both contributed approximately 2%. These results undoubtedly partly reflect the composition of street plantings and front yard trees and shrubs.

Table 1 Family and species recorded (dicotyledons unless marked [G] for gymnosperm or [M] for monocotyledon)

Family	Scientific (and common) names	No of species
Apocynaceae	*Nerium oleander* (Oleander), *Plumeria* sp. (Frangipani), *Trachelospermum jasminoides* (Star Jasmine)	3
Araucariaceae	*Araucaria cunninghamii* (Hoop Pine), *A. heterophylla* (Norfolk Island Pine)	2
Asparagaceae[M]	*Dracaena trifasciata* (Mother-in-law's Tongue)	1
Bignoniaceae	*Jacaranda mimosifolia* (Jacaranda)	1
Caprifoliaceae	*Weigelia* sp. (Weigelia)	1
Casuarinaceae	*Allocasuarina littoralis* (Black She-oak), *Casuarina glauca* (Swamp She-oak)	2
Cunoniaceae	*Ceratopetalum apetalum* (Coachwood), *C. gummiferum* (Christmas Bush)	2
Cupressaceae[G]	*Callitris muelleri* (Mueller's Cypress), Cypress, Cypress-like trees, *Sequoia* sp.?, *Sequoia giganteum* (Giant Redwood)	5+
Elaeocarpaceae	*Elaeocarpus reticulatus* (Blueberry Ash)	1
Ericaceae	*Rhododendron* (Rhododendron)	1
Fabaceae	*Pararchidendron pruinosum* (Snow Wood)	1
Lauraceae	*Cinnamomum camphora* (Camphor Laurel)	1
Loranthaceae	*Muellerina eucalyptoides* (Mistletoe)	1
Lythraceae	*Lagerstroemia indica* (Crepe Myrtle)	1
Magnoliaceae	*Magnolia* x *soulangeana* (Saucer Magnolia)	1
Malvaceae	*Brachychiton acerifolius* (Illawarra Flame Tree)	1
Melastomaceae	*Tibouchina urvilleana* (Tibouchina)	1
Myrtaceae	*Acmena smithii* (Lilly Pilly), *Acmena* spp., *Backhousia citriodora* (Lemon Myrtle), *Callistemon citrinus* (Crimson Bottlebrush), *C. salignus* (Willow Bottlebrush), *C. viminalis* (Weeping Bottlebrush), *Corymbia gummifera* (Red Bloodwood), *C. maculata* (Spotted Gum), *Eucalyptus globoidea* (White Stringybark), *E. nicholii* (Narrow-leaved Black Peppermint), *E. paniculata* (Grey Ironbark), *E. pilularis* (Blackbutt), *E. punctata* (Grey Gum), *E. resinifera* (Red Mahogany), E. scoparia (Wallangarra White Gum), *Eucalyptus* sp., *Lophostemon confertus* (Brush Box), *Melaleuca quinquinervia* (Broad-leaved Paperbark), *Melaleuca* sp., *M. styphelioides* (Prickly-leaved Paperbark), *Syncarpia glomulifera* (Turpentine), *Tristaniopsis laurina* (Water Gum)	22+
Oleaceae	*Fraxinus excelsior* (Ash)?, *Notelaea longifolia* (Large Mock-olive), *Olea europea* (Olive)?	3
Phyllanthaceae	*Breynia oblongifolia* (Coffee Bush), *Glochidion ferdinandi* (Cheese Tree)	2
Pinaceae[G]	*Cedrus deodara* (Deodar Cedar), *Pinus radiata* (Radiata Pine)	2
Pittosporaceae	*Pittosporum undulatum* (Sweet Pittosporum)	1
Podocarpaceae[G]	*Podocarpus elatus* (Illawarra Plum)	1
Proteaceae	*Banksia integrifolia* (Coast Banksia), *B. serrata* (Old-man Banksia), *B. spinulosa* (Hairpin Banksia), Grevillea hybrid, *Macadamia tetraphylla* (Macadamia), *Stenocarpus sinuatus* (Firewheel Tree)	6
Rosaceae	*Photinia* sp., *Prunus* sp., *Pyrus* sp.?, *Rhapheolepis indica* (Indian Hawthorn)	4
Rubiaceae	*Coprosma repens* (New Zealand Laurel)	1
Rutaceae	*Murraya paniculata* (Orange Jasmine)	1
Santalaceae	*Exocarpus* sp. (Ballart)	1
Sapindaceae	*Acer negundo* (Box Elder), *A. palmatum* (Japanese Maple)	2
Theaceae	*Camellia japonica* (Camellia), *Gordonia axillaris* (Fried Egg Plant)	2
Ulmaceae	*Ulmus* sp. (Elm)	1
Zingiberaceae[M]	*Alpinia zerumbet?* (Shell Ginger)	1
Approx total		76+

Dense infestations almost always involved Turpentine (approximately 37% of recordings). Approximately 8% of recordings were Brush Box (Fig 4) and over 5% of our records were Willow Bottlebrush. These three Myrtaceae species were approximately 50% of our records. Other common recordings were Japanese Maple (Fig 5), Saucer Magnolia (Fig 6), Photinia and Jacaranda (Fig 7). Again, this partly reflected the composition of front gardens and street trees.

Fig 4 Spanish Moss can dramatically alter the streetscape when Brush Box is a dominant tree

Fig 5 Japanese Maple often carries abundant Spanish Moss

Fig 6 Spanish Moss flourishes on deciduous trees such as Saucer Magnolia

Fig 7 Jacaranda is a favoured host of Spanish Moss

Only two species of Eucalyptus carried substantial amounts of Spanish Moss. The main species on which it flourished was Red Mahogany. We recorded serious infestations at Turramurra and Toronto, and it has also been recorded at North Rocks by Rachel Yeomans (3). Several Blackbutts were recorded but in all cases the infestation was sparse to medium and the Blackbutts were underneath or immediately adjacent to densely infested Turpentines. These were very unusual sightings as we had searched dozens of Blackbutts for Spanish Moss.

Very few of the huge number of other species of indigenous and non-local Eucalyptus, Angophora and Corymbia were recorded carrying Spanish Moss. Despite the abundance of Sydney Red Gum, Spanish Moss was only recorded on it once, when a Noisy Miner (*Manorina melanocephala*) had used it in a nest. The Spanish Moss was still confined to the nest. A very few individuals of the non-local Wallangarra White Gum, Narrow-leaved Black Peppermint and the local White Stringybark, carried festoons on branches. Grey Ironbark and Grey Gum carried only sparse Spanish Moss on outer twigs and branches. Only one Red Bloodwood, was seen with abundant dense festoons of Spanish Moss, even though this species is very common in the area. It was conspicuously on a large dead branch. The only Spotted Gum recorded carried infrequent festoons on a few twigs and outer branches.

Fig 8 Spanish Moss fails to flourish
on Camphor Laurel

Other species that failed to support healthy Spanish Moss included Camphor Laurel (Fig 8). In both cases the support trees were very unhealthy and yellowed with unusually sparse foliage and the Spanish Moss was sparse. Other abundant trees that did not support infestations included She-oak species and Southern Magnolia. Of all the figs viewed only one Port Jackson Fig carried a few strands, unlike records in the Atlas of Living Australia. Spanish Moss was recorded on two semi-parasitic species (both on Red Mahogany): Mistletoe and Ballart.

Spanish Moss occurred on the native gymnosperms, Hoop Pine, Norfolk Island Pine, Mueller's Cypress and Illawarra Plum.

We also recorded Spanish Moss in many introduced gymnosperms, including Cypress species, where it was virtually invisible from the outside but was prolific inside the dense canopy. We were surprised to find it flourishing in a Radiata Pine, despite the literature repeatedly stating it didn't flourish in pines (28).

We recorded Spanish Moss flourishing on the monocotyledons, Mother-in-law's Tongue and Shell Ginger, after it had fallen from the trees above.

At the historic Gordon property, Tulkiyan, Spanish Moss flourished on a wide range of Australian east coast rainforest trees. All layers and all parts of Lilly Pilly were densely covered with Spanish Moss, to the point that the host appeared to be dying. The surrounding Coachwood, Lemon Myrtle, Cheese Tree, Firewheel Tree and Snow Wood, all carried varying densities of Spanish Moss. Except for Snow Wood, all had been recorded elsewhere as support plants. Snow Wood was the only species in the Fabaceae family we recorded.

Age of infestations and rate of spread

In a quick search of Trove, Spanish Moss was mentioned in 1889 in the *Brisbane Courier* (12 August) in a report of a meeting of the Queensland Acclimatisation Society. The first record of Spanish Moss in the Australian Virtual Herbarium (6) appears to be in 1984, long after residents of northern Sydney remember it in the area, e.g. it was well established in Mt Kuring-Gai in 1973.

Our results indicate that serious infestations range from as young as 40 to 50 years old to possibly as old as 70 to 100 years. These would be very rare, only possible at Tulkiyan, Gordon but early photos show no host trees present.

The rate of spread was difficult to determine but two residents of 35 to 50 years remembered initial infestation and it had spread outwards 30 to 50 m in the intervening years, a spread rate of approximately 1 m/year. On the other hand, the Spanish Moss recorded in a Noisy Miner nest appeared to be 70 m from the nearest source, a large jump in one year.

Characteristics of infestations

As this was a preliminary survey driven by notifications, we were only able to carry out very basic analyses (see Tables 2 and 3). All percentages are therefore only a rough indication of infestation patterns.

Abundance

Just over 40% of infestations were sparse and only 23% were abundant (Figs 9 to 11).

Festoon thickness

The majority of festoons were dense (Fig 9) and less than 10% were sparse (Figs 10 to 11).

Position on host tree

The majority of infestations (61%) were recorded in the middle layer of trees with the next most common layer the lower portion of trees. Less than 10% of infestations were in the upper layer and only 8% of infestations covered all layers. We chose a simple four zone system for location, unlike Miranda et al. (44).

Height on host tree

Only 12% of infestations were recorded within easy reach and 15% were at the inaccessible height of >15 m.

Table 2 Characteristics of infestations

Abundance	**Percentage**
Sparse – very few festoons	43
Medium – obvious festoons	33
Abundant – visible from a distance	23
Festoon thickness	
A few strands to spidery appearance	8
Mid-dense – can see through festoon	27
Dense – unable to see through festoon	65
Position on host tree	
Lower	23
Middle	61
Upper	8
All layers	8
Height on host tree (m)	
0 to 2	12
2 to 10	57
10 to 15	16
>15	15
Festoon length (mm)	
Strands only	2
<100	1
100 to 500	14
500 to 1 000	20
1 000 to 2 000	30
2 000 to 3 000	24
3 000 to 4 000	9

Fig 9 Abundant dense festoons of Spanish Moss on a Brush Box

Fig 10 Sparse mid dense Spanish Moss on Water Gum

Fig 11 Sparse festoon of Spanish Moss

Fig 12 Spanish Moss twisted around tree trunks

Fig 13 Turpentine leaves
smothered with Spanish Moss

Fig 14 Hoop Pine leaves carrying
Spanish Moss (near Hamilton Park, Turramurra)

Fig 15 Lilly Pilly leaves overwhelmed by
Spanish Moss (Tulkiyan, Gordon)

Fig 16 Firewheel tree leaves
dominated by Spanish Moss

Festoon length

The most common festoon length was 1 to 2 m long (30%) with lengths of 0.5 to 3 m making up 74%. The longest festoons were 3.1 to 3.2 m long on a Turpentine and Lilly Pilly in infestations approximately 45 to 50 years old. On favourable hosts, short festoons are not going to stay short.

Distribution on the support trees

As shown in Table 3, branches were the most common support (56%) with most infestation being of medium density. The second most common support were leaves (26%) but coverage was generally sparse (16%). Tree trunks (Fig 12) were the least favoured support (17%) with sparse to medium coverage being the norm.

Only 12 host tree species (26%) had Spanish Moss covering the leaves and of these:

- 94% of Turpentines (Fig 13) had some leaf coverage and 22% of these were densely covered;
- 52% of Brush Box (Fig 9) had some leaf coverage but the vast majority were only lightly covered;
- the natives Hoop Pine (Fig 14), Mistletoe, Lilly Pilly (Fig 15), Firewheel Tree (Fig 16), Macadamia and Prickly-leaved Paperbark also had festoons over their leaves;
- introduced Deodar, Japanese Maple, Photinia and Crepe Myrtle occasionally had Spanish Moss over the leaves.

Table 3 Distribution of Spanish Moss on support trees

Support structure	Sparse (%)	Medium (%)	Abundant (%)	Total (%)
Leaves	16	6	4	26
Branches	19	28	9	56
Trunk	9	6	1	17
All parts				1
				100

DISCUSSION

Why does Spanish Moss flourish on some trees and not others?

Firstly, Spanish Moss can grow anywhere – on wire (Fig 17), balustrades and wooden structures – but it undoubtedly flourishes on some tree species and not others. We can only speculate on the cause due to the uncertain age of the infestations and the paucity of information on the biology of Spanish Moss and the host trees. Numerous explanations have been proposed overseas but detailed research on Sydney bushland trees and their interaction with Spanish Moss is urgently required (Table 4).

Fig 17 Spanish Moss can grow anywhere, even on wires

Fig 18 Underside of Turpentine leaves spotted with fungi which may aid Spanish Moss to flourish

Table 4 Observations and possible explanations for Spanish Moss infestations

Explanations	Observations	Comments
Preference for sunny locations	No	Usually in the middle layer of the support plant. Often heavily shaded, e.g. Japanese Maple. Often in sheltered locations with reduced sunlight.
Temperature, moisture and light	Yes	Complex. Usually in the mid layer of a tree but as it is a light loving, temperature, moisture and leachate may be involved.
Grows better on dead trees, branches and twigs than live ones	Yes	Spanish Moss will grow on dead or unhealthy branches and trees on which it doesn't normally flourish, e.g. Camphor Laurel, Red Bloodwood, Black She-oak and some eucalypts.
Stem flow	Uncertain	Observations were insufficient to comment.
Foliar mineral leaching	Yes	The obvious explanation for the change in growth form from Red Mahogany (dangling festoons) and Mistletoe (where it swamped the leaves). It preferentially grew over leaves on Turpentine.
Presence/absence of non-vascular epiphytic species such as lichens and fungi	Uncertain	This could be possible. No specific notes were taken on non-vascular epiphytes.
Presence/absence of foliar fungi	Yes	Suggested after consulting Carnegie et al. (15). The favoured support tree, Turpentine, always has fungi on older leaves (Fig 18). Leaves are often parasitised by moth larvae (33).
Allelopathy, release of chemical by an organism that **inhibits** the growth of nearby plants (7)	Uncertain	Possible on species such as Camphor Laurel and Black She-oak and some eucalypts.
Water holding capacity of the bark	No	Spanish Moss can flourish on the smooth bark of Brush Box and Crepe Myrtle which presumable have low water holding capacity. But its favoured support tree, Turpentine, has thick spongy bark (33).
Bark sloughing and unstable bark	Yes	This may well have a strong influence, e.g. Sydney Red Gum sheds annually, but Brush Box only sheds its rough bark from the upper trunk and branches and this is a favoured species.
Tree size	Uncertain	Tree size was not recorded.

Dispersal

Wind is an obvious dispersal agent, when festoons sway or fall they can catch on the same or different hosts. We never saw evidence of fragments being caught in the wind and blown to nearby trees. Spanish Moss was more common on the roadside of trees in several observations, and we speculated that it may have been spread by wind caused by vehicles. When it falls to the ground it appears to die.

Fig 19 Noisy miner nest with flourishing Spanish Moss

We only documented three cases of dispersal by fauna: residents have seen Satin Bowerbirds (*Ptilonorhynchus violaceus*) removing fragments, and we recorded it in a Noisy Miner nest (Fig 19) and in an Eastern Ringtail Possum (*Pseudocheirus peregrinus*) drey. It has been found in an Olive-backed Oriole (*Oriolus sagittatus*) nest (14). Despite the sparsity of documented evidence, widespread dispersal by birds and possums seems likely. The dead construction material in nests and dreys may help Spanish Moss to subsequently flourish.

People were a major cause of dispersal, and solid clumps of Spanish Moss folded over tree forks were a clear giveaway. Several residents we spoke to encouraged Spanish Moss in their gardens and passers-by often collected it. We saw it draped over fences (Fig 20), porch railings, arches (Fig 21), used as compost behind an epiphytic orchid (Fig 22), placed on wire hooks on lower tree branches, used as fibre in a hanging basket (Fig 23) and on plants being sold at community events. An increasingly important dispersal mechanism may be movement of large potted shrubs, such as Frangipani draped with Spanish Moss (Fig 24) from one residence to another in an increasingly mobile population.

Fig 20 Spanish Moss used to decorate a fence

Fig 21 Spanish Moss decorating an arch

Fig 22 Spanish Moss used as compost behind a crucifix orchid

Fig 23 Spanish Moss dangling from a hanging basket

Fig 24 Spanish Moss placed in a Frangipani fork. Note the difference in growth form to that in Fig 17

We found no evidence of seedlings during our survey between November and February.

So many residents commented on its rapid increase in density, length and spread over the last few years, that we consider that Spanish Moss is no longer a sleeper weed (31). Serious exponential growth is happening now.

Distribution

The combination of dispersal agents and the age of infestations has led to large gaps between infestations. These gaps contain apparently suitable trees and the only explanation we can think of is that Spanish Moss has simply not arrived there yet.

Many of the most serious Turpentine infestations were in the upper Lane Cove River catchment, a reflection of the distribution of STEP members and the abundance of Turpentine trees (Fig 25).

Recordings of infestation in bushland conditions included Grayling Street Reserve, West Pymble (Fig 26), Terra Ulong Creek, Pennant Hills and most worryingly Wallumatta Nature Reserve, North Ryde (Fig 27). Due to the methodology, most recordings were in street trees and front gardens.

Fig 25 Severe infestations of Spanish Moss on Turpentine trees in the Upper Lane Cove Valley: Terra Ulong Creek Pennant Hills, Cavendish Street Pennant Hills, Mt Pleasant Avenue Normanhurst, Hamilton Park Turramurra, Warragal Road Turramurra and Grayling Street Reserve West Pymble

Fig 27 The southeast corner of Wallumatta Nature Reserve with early stages of Spanish Moss infestation, November 2023

Fig 26 Grayling Street Reserve from Grayling Road, December 2023

Abundance within the Myrtle family

There is no apparent affinity to any tribe in the Myrtaceae, subfamily Myrtoideae (69) as Spanish Moss was found on plants from eight of the 15 tribes, with Lophostemoneae (Brush Box), Melaleuceae (some Melaleuca and Callistemon), Backhousieae (Lemon Myrtle), Syzygieae (Syzygium and Acmena) and Syncarpieae (Turpentine) being major hosts. Kanieae (Water Gum), Eucalypteae (Eucalyptus, Corymbia and Angophora) and Leptospermeae (Lemon-scented Tea Tree) rarely supported Spanish Moss.

Regardless of eucalypt classification (24, 46) there appeared to be no link between the tendency of Spanish Moss to flourish on different species at subgenera level. The only Eucalyptus we repeatedly recorded Spanish Moss flourishing on was Red Mahogany in the subgenera Symphyomyrtus (Fig 28). Other species in Symphyomyrtus (Grey Gum, Grey Ironbark and Sydney Blue Gum) carried little or no Spanish Moss, even when they were adjacent to infestations.

In the subgenera Eucalyptus, Blackbutt only supported Spanish Moss when it was immediately adjacent to or overtopped by Turpentine (Fig 29) but other species in the subgenus Eucalyptus recorded near infestations, e.g. Sydney Peppermint and Scribbly Gum, either had no Spanish Moss or a few wisps that were failing to flourish. Only one, White Stringybark, was recorded with substantial Spanish Moss.

Corymbia species and Sydney Red Gum were not favoured hosts.

Fig 28 Spanish Moss in Red Mahogany, Warragal Road, Turramurra, December 2023

Fig 29 We only found Blackbutt carrying Spanish Moss when it was immediately adjacent to severe infestations on Turpentine

Effect on trees and plant communities

We believe that Spanish Moss can kill specific species, e.g. Turpentine and Lilly Pilly, by smothering leaves and preventing photosynthesis. Environmental stressors such as drought, saturated soil, weedy understorey, gardening impacts and pathogen outbreaks could hasten tree decline and death as leaf production of the host may be out paced by Spanish Moss. In some species, e.g. Cheese Tree, it was hard to determine whether the Spanish Moss was abundant because the tree was dying or whether it was aiding the death of the host.

Effects on bark were not specifically noted but the bark environment could be substantially altered on both branches and trunks in dense infestations. Changes to humidity may lead to fungal decay and Spanish Moss would disrupt the normal epiphytic community of lichens, moss, fungi and bacteria and their associated communities.

Plant communities that have Turpentine, Lilly Pilly, Brush Box (Fig 30), Cheese Tree and other rainforest species as major components of their tree canopy are under threat from Spanish Moss. These vegetation classes cover a large percentage of the east coast and ranges of NSW and include Northern Warm Temperate Rainforests, Southern Warm Temperate Rainforests, Littoral Rainforests, North Coast Wet Sclerophyll Forests and Northern Hinterland Wet Sclerophyll Forests (39). We can see no barrier to Spanish Moss dispersal and growth along the coast unless well-planned efforts are made to control it as it is already present along the north coast of NSW (3).

At a more detailed level, many plant community types (56) may be severely affected in the long term, e.g. Blue Gum High Forest (ID 3136), Sydney Turpentine-Ironbark Forest (ID 3262), Northern Turpentine-Brush Box Wet Forest (ID 3174), Sydney Enriched Sandstone Moist Forest (ID 3176), Northern Hinterland Grey Gum-Turpentine Mesic Forest (ID 3253), Northern Escarpment Brush Box-Tallowwood-Maple Wet Forest (ID 3166) and Northern Brush Box Subtropical Wet Forest (ID 3165).

We also have concerns about ecosystems containing Crimson Bottlebrush, Willow Bottlebrush, Weeping Bottlebrush (Fig 31) and Prickly-leaved Paperbark but we were surprised by the low rate of infestation in Broad-leaved Paperbark in street trees.

Fig 30 Spanish Moss flourished on Brush Box in suburbia; we presume it would do the same in natural plant communities

Fig 31 Weeping Bottlebrush is a favoured host of Spanish Moss

Effect on ecosystems

In its native habitat, Spanish Moss increases habitat simply by its structural complexity, and it can be an important nursery for small organisms (9). Locally, coverage of the tree surface by Spanish Moss would severely alter the normal cohort of invertebrates that suck sap, form galls, tunnel into tissues, chew chunks away, bore holes and, girdle twigs on trees. It would also alter the normal epiphytic community of viruses, bacteria, fungi and lichens. This would alter opportunities for predators such as birds, parasites, and pathogens. The only specific species interaction we noted were a Sulphur-crested Cockatoo (*Cacatua galerita*) carefully lifting aside festoons of Spanish Moss to feed on the bark underneath and a Grass Lynx Spider on the outside of a festoon.

Extra material to line nests might be provided, but the distribution of dense Spanish Moss over branches must reduce nesting sites for a wide range of birds.

We are also concerned about the effect of Spanish Moss on Grey-headed Flying-fox, listed as vulnerable at Commonwealth level (4). Turpentine is a significant food tree for the Grey-headed Flying-fox in spring (22) and their potential loss may be devastating. We are also concerned that the Grey-headed Flying-fox may become entangled in Spanish Moss while seeking nectar and pollen. See Fig 32.

Over time, Spanish Moss would alter basic water and nutrient cycles in an ecosystem as it changes the architecture, leaf morphology and chemistry of the canopy. Throughfall enriched with dissolved organic carbon, ammonium and potassium with would be greatly reduced in dense infestations as the exterior of Spanish Moss absorbs rain. Stemflow would also be reduced as the flow down branches would be interrupted and rechannelled into festoons. This would lead to a reduction and redistribution of soil water (29, 38, 43).

Effect on microclimates

Superficial observations indicated that moderation of wind, temperature and humidity was likely within individual dense festoons, in the mid layer of heavily infested trees and sometimes over the whole tree. This is in agreement with Borst et al. (9). Our observations indicated that Spanish Moss is likely to flourish in sheltered humid areas, but is not exclusive to them, e.g. Grayling Reserve and over the creek on Lofberg Road, West Pymble.

Effect of climate change

Predicted climate change may have little impact on Spanish Moss distribution as it is capable of flourishing over a huge range of conditions. However, a decrease in frost may help it to flourish and a possible increase in high intensity fires may reduce infestations.

Fig 32 Flying Foxes may be impacted by Spanish Moss as Turpentine is a favoured food in spring and they may become tangled in festoons

Fig 33 Fire intensity and flame height could increase in areas with dense infestations of Spanish Moss

Effect on fire regimes

We are concerned about possible enormous changes in fuel type and distribution in natural ecosystems (20) as long, dense festoons would dramatically change the quantity of fine fuels and decrease the separation between the ground layers and the canopy. See Fig 33.

Areas that fire rarely reaches, such as urban bushland and rainforest, could suffer from rare dangerous high intensity canopy fires while the low flame height of prescribed and cultural burns may fail to reach the canopy and control Spanish Moss.

Spanish Moss is not fire resistant nor fire tolerant and in its native habitat frequent fire is a limiting factor for Spanish Moss distribution as fire damages trees and burns the festoons of Spanish Moss on the lower branches (28, 62).

Control

One of the main barriers to control is the fact that many gardeners and horticulturists love it and actively spread it. Education about its damaging impacts is needed for gardeners, horticulturalist, arborists, park and bushland managers and professional organisations. Spanish Moss needs to be added to the NSW WeedWise website (48) as a Sydney issue and added to the Sydney Weeds Network website (57).

The ideal answer to control would be a specific biological control but its very low protein content makes it largely unpalatable (9). We didn't find any reference for suggested species despite several authors describing invertebrate herbivores (9, 16, 28).

Fig 34 Large expensive equipment that is hard to manoeuvre on the ground and in the canopy may be required when infestations are high up

Hand removal is often recommended as the best way to kill Spanish Moss (27) but in our survey only approximately 12% was in easy reach. Rakes, ladders, professional tree climbers, industrial vacuum cleaners and specialised equipment such as spider lifts (Fig 34) and elevated platforms would be needed in many infestations. Large equipment would damage both the soil, shrub layer and canopy in gardens and bushland and access may prevent their use. Fire could be useful for its control.

Chemical control methods in the Americas involve spraying festoons with various solutions (27, 54). Apparently, a mix of 0.25 of a cup of potassium bicarbonate per 3.78 litres of water (one gallon) works quickly and does not damage trees. Baking soda (sodium bicarbonate), to the same concentration, is immediately effective, but the high salt content may damage new growth on trees. Copper sulphate is the most effective but slowest acting solution for removing Spanish Moss. It can damage new or tender growth on trees and harm surrounding plants. It can also stain. The recommended mix is 10 parts of water to 1 part copper sulphate and 1 part lime.

Experimentation would be needed in Sydney conditions, particularly in bushland, to assess the effects of any of these treatments on Spanish Moss, the support tree, neighbouring plants, non-vascular species such as lichens, fauna and the soil as pH, salinity and nutrient content may be altered.

It must be included as a priority weed in the next iteration of the Greater Sydney Regional Strategic Weed Management Plan 2023–2027 (41). We recommend that it be classified as a state priority weed and its sale prohibited due to its threat to many ecosystems along the coast and ranges of NSW. It needs to be added as a separate threat to Sydney Turpentine-Ironbark Forest in the Sydney Basin Bioregion (49).

There is a general biosecurity duty for any person who deals with a plant that poses a risk of causing an adverse effect on the economy, the environment or the community and who knows, or ought to know about the risk the plant poses, has a legally enforceable duty to prevent, eliminate or minimise the risk of that impact occurring (41).

RECOMMENDATIONS

We recommend an urgent multi-pronged attack on Spanish Moss.

Individuals

Remove all reachable festoons in your garden and put them into the green bin.

Control all festoons in garden trees by other means, e.g. spraying when safe effective methods have been established.

Do not give Spanish Moss to friends, neighbours, passers-by and the local community.

Join campaigns to alert the local community and authorities to the threat posed by Spanish Moss to bushland and gardens.

Authorities

Control authorities, e.g. state government, local councils, local land services and National Parks and Wildlife Service to urgently remove and control Spanish Moss.

Educate the community about the threat posed by Spanish Moss to bushland.

The Threatened Species Scientific Committee needs to add Spanish Moss as a specific threat to the Critically Endangered Sydney Turpentine-Ironbark Forest.

Regulatory

Spanish Moss must be added to:

- the next iteration of the Greater Sydney Regional Strategic Weed Management Plan and all other relevant regional strategic weed management plans; and
- these plans at a classification level that enables its eradication and containment, prohibition of sale and distribution, e.g. as a regional priority weed.

Research

Immediate research is needed into:

- why Spanish Moss flourishes on Turpentine, Brush Box and other rainforest species but not on most eucalypts;
- the ecological consequences of infestation on individual trees and native plant communities;
- the rate of growth and variation of growth with weather;
- safe effective control options in Australian conditions; and
- fire ecology.

Education

Education about the threat posed by Spanish Moss to bushland through:

- TAFE NSW and private vocational providers – Spanish Moss must be included on weed lists for horticultural, landscape, conservation and ecosystem management courses;
- Community groups – conservation groups (many are members of the Nature Conservation Council), gardening clubs (many are members of Gardening Clubs of Australia), Landcare, Greening Australia;
- Professional organisations – Australian Association of Bush Regenerators, The Society for Ecological Restoration Australasia, Ecological Society of Australia, Australian Institute of Horticulture;
- Gardening media – TV gardening and home improvement programs such as Gardening Australia, radio programs, magazines such as *ABC Gardening Australia Magazine*, *Landscape Architecture Australia*, *Australian House & Garden*; and
- Social media – Facebook groups such as *NSW Introduced Plant Identification* and *Bush Revegetation and Regeneration*.

CONCLUSION

Spanish Moss must be treated as a serious environmental weed otherwise Turpentines, Lilly Pillys and other rainforest trees will turn into grey curtains of swaying Spanish Moss. Currently gardens act as a source of Spanish Moss for spread to bushland. Gardeners need to treat it as a threat to their trees and green spaces, not as an interesting ornament. Most festoons we recorded were well under 3 m long but overseas records show they can be 8 m long, a frightening image.

Spanish Moss will be expensive and difficult to control as most of it is out of easy reach. The sooner gardeners, park and natural area managers commence a coordinated program of removal the cheaper and more effective it will be.

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APPENDIX. SPANISH MOSS LOOK ALIKES

Not everything that dangles from trees is the introduced Spanish Moss.

Papillaria species (Hanging Mosses)

Papillaria is a moss with seven species known in Australia, four of which are recorded in the Sydney area, *P. crocea*, *P. flavolimbata*, *P. leuconeura* and *P. flexicausli*s (1). These mosses are common in the canopies and on tree branches and trunks in tropical, subtropical and temperate forest. They can also be found in drier habitats and at cooler elevations and latitudes (5). In the picture below, the green Hanging Moss (right) can be confused with silver Spanish Moss (left).

Usnea species (Beard Lichens)

Usnea is a genus of lichens that can also dangle spectacularly from trees with numerous records listed as *Usnea* species or *U. hirta* (2).

Cassytha species (Devil's Twine)

Cassytha species (Devil's Twine) are herbaceous twiners with thread-like stems that are hemiparasitic on shrubs or trees. They can form dense bunches or dangle down from their host.

Mistletoe

A less likely plant to confuse it with are the local Mistletoes, these dangle but have broad leaves.