

I, Kathryn Bayliss, thank you for allowing me to table the second part of my Statement, Evidence/Representations, and written material in support of my submission on Ecosystems & Indigenous Biodiversity.

The panel is welcome to contact me if they have any questions or wish to discuss anything.

I uphold my first Submission for the CHBDC Proposed May 2021 and the documents and statement in the folder named "Kathryn Bayliss - Part 1. Statement for CHBDC District Plan, 1. Natural Environment – Natural Features and Landscapes.

I will not repeat them again in this statement.

I disagree with the Council Planners' (s42A) reports Recommendation for my submissions to be rejected.

I am seeking to Central Hawke's Bay District Council to Prohibit clearance of indigenous vegetation, except for ECO-R3(1)(b). And to make Trimming discretionary and also limited to ECO-R3(1)(b).

1.

Council's ecologist, Mr Kessels, states "... in the case of early regenerated mānuka and kanuka (less than 15 years old), usually reverting on steep hill country farmland, the relevant criterion have been ignored where it was possible to determine from viewing historical aerial photography.

However, while we have adopted this approach for recent secondary regrowth mānuka and/or kanuka on farmland, there are situations where ecosystems dominated by these two species may still be ecologically significant. Mature mānuka and kanuka stands (those over 15 years old) are likely to have a regenerating understory increasing potential to harbour At-

Risk or Threatened species. In addition, some wetland types, such as peat bogs, are often dominated by mānuka. Furthermore, it is possible that some coastal species of previously At-Risk or Threatened kanuka species are present within the CHBDC. These stands are likely to be ecologically significant. As such, their significance cannot be determined from aerial photography alone, and these areas would require ground-truthing in order to ascertain their SNA status with any degree of certainty."

If trimming and clearance is permitted in certain circumstances there will be no control over the risk that significant indigenous vegetation, including mānuka and kanuka, will be cleared. If owners want to clear or trim areas of indigenous vegetation, they should have to have them inspected and ground-truthed first.

As regenerated mānuka and kanuka (less than 15 years old) is usually reverting on steep hill country farmland it is all the more important to protect it for erosion control. Shrubs and trees also have an important role in absorbing rain and preventing flooding.

We must protect and restore existing natural indigenous forests and trees to help stop climate change and loss of biodiversity. The value of intact forests is seldom highlighted. Millions of dollars of public money is spent on planting of trees for erosion control, to stop climate change and help with biodiversity. It negates much of the work done and money spent to allow clearance of indigenous vegetation, even if it only a certain area each year. Over the years and over different properties this could add up to big loss.

2.

Excerpts:

i. Hawke's Bay Regional Council Meeting of the Environment

and Integrated Catchments Committee. 10 November 2021  
Erosion Control

Subject: Biodiversity - achieving our biodiversity outcomes

1. This item provides an overview of cross Council investment in biodiversity-related programmes and upcoming challenges in the biodiversity space that will potentially require resourcing through the 2024-34 Long Term Plan.

Executive Summary

2. The Global Biodiversity Crisis - The world is witnessing a large-scale degradation of nature, resulting in an unprecedented loss of species. Current global biodiversity trends indicate a rapid loss of both the area and the quality of natural ecosystems. The recent rapid loss of biodiversity suggests the planet is witnessing its sixth mass extinction wave, which is human-induced. Despite an increase globally in policies and actions to support biodiversity, biodiversity loss has worsened. On the current trajectory, it is predicted that approximately half of all species are at risk of extinction by the end of the century.

3. New Zealand is listed as the worst country in the world for many threatened species. More than 4000 species are currently threatened or at risk of extinction. The drivers behind biodiversity loss are multiple and complex of which no one entity can solve alone.

4. The Regional Council has a range of programmes that help protect or enhance our environment; however, most of these are focused on water quality. Few are aimed at addressing terrestrial or marine biodiversity decline. This item outlines those programmes that help protect and enhance biodiversity and the internal collaboration in delivering them.

Right Tree, Right Place

26. There is expected to be around 10,000 ha of the highest risk land planted over the next ten years by grant funding

initiatives directly supported by Council such as through Council's investment of \$30M in the Erosion Control Scheme. However, the scale of the regional context represents significant challenges, risks and opportunities, which the RTRP pilot is aimed to address.

27. After considering a Business Case and public consultation through the 2021-31 Long Term Plan process, Council agreed to fund \$4.8M toward the pilot of the RTRP concept.

### Erosion Control Scheme (ECS)

28. In 2018, Council established the Erosion Control Scheme. Its purpose is to enable tree planting and other erosion control work to occur on highly erodible land and enables this by providing significant financial support for these erosion control works.

29. The ECS enables targeted erosion control to be delivered on highly erodible land where other initiatives are not deemed appropriate e.g. RTRP, this work is agreed to in partnership with landowners. The ECS is a key tool for the Catchment Delivery Team to engage with and support landholders with land at high risk of erosion. The 2018 - 2028 LTP provided for \$30 million over the 10-year term of the LTP to support this programme of work.

30. This scheme enables tree planting and other erosion control works to occur on those areas of land that are not suitable for commercial planting purposes. Examples of such land includes (but is not limited to) remote locations, infertile soil types, smaller erosion prone areas, and areas where commercial tree planting is inappropriate. Within such areas, the Erosion Control Scheme aims to:

30.1. Reduce soil erosion

30.2.. Improve water quality through the reduction of sedimentation into waterways

30.3. Improve terrestrial and aquatic biodiversity through

habitat protection and creation

ii.

Climate change and agriculture: Understanding the biological greenhouse gases

Dr Jan Wright. Parliamentary Commissioner for the Environment October 2016 (Excerpt attached, Full Report available at: [www.pce.parliament.nz](http://www.pce.parliament.nz))

In the above report Dr Jan Wright looked at a very different approach to dealing with biological emissions using trees to soak up and store carbon dioxide. Forests can be used for offsetting – taking carbon dioxide out of the atmosphere to compensate for the biological emissions entering the atmosphere.

iii.

A review of *Leptospermum scoparium* Myrtaceae in New Zealand.pdf

In the above report (attached), it informs about the need for more understanding of the Manuka species' variation which will assist both its conservation roles and economic uses, and the need to sustain genetically distinct varieties is emphasised. Ecologically, the species has a dominant role in infertile and poorly drained environments, and a wider occurrence as a shrub species in successions to forest. Some people may regard it as a woody weed of pasture but it has a useful species for erosion control, carbon sequestration, and vegetation restoration. The main economic products derived from the species are ornamental shrubs, essential oils, and honey. The species' development as an ornamental plant and further definition of the pharmacologically active components are recommended as priority areas for research.

4.

i.

Often natural original and secondary regrowth of indigenous vegetation, including mānuka and kanuka, is considered by only the dominant species which are easily observed. But in reality they are diverse ecosystems on, around and under the shrubs and trees and also under the ground. On the trees epiphytes, mosses and lichens often live in symbiosis with them. Invertebrate and vertebrate animals including insects, bats and birds, often live among them and are dependent on them. Underground soil mycorrhizal fungi live in symbiosis with plant roots and as well many other species.

New Zealand native forests are complex ecosystems. Trees offer shelter and nesting materials for birds. They also provide habitats for many smaller species such as lizards and thousands of invertebrate species.

There is diversity of trees, providing the structure of the forest. A healthy forest will have many layers of plants – from seedlings and small plants such as ferns and mosses on the floor to the canopy trees tops. This layering is called stratification. The different layers often create different microclimates, providing specialised habitats – almost mini-ecosystems for a range of different species.

In 2017 in "New Zealand's Threatened Species Strategy" by the Department of Conservation, it stated:

"...more than 3000 of native species were classified as threatened or at risk. Around 800 of these were at risk of extinction.... Knowledge gaps are a significant challenge - we do not know enough about some species to assess them." Some species are still unknown and waiting to be discovered.

ii.

The ecology of canopy communities — treetop islands of

biodiversity—is almost unknown. Only in 2008, for her PhD dissertation at Lincoln University, Kathryn Affeld made the first comprehensive study of plants and invertebrates living in the New Zealand forest canopy. She climbed into the crowns of 40 northern rata on the South Island West Coast and found 170 plant species and almost 450 invertebrate species—“an astonishingly diverse and complex canopy flora and fauna”, she wrote in her thesis.

iii.

Another world-wide topic for research in recent years is Mycorrhizal fungi.

Julie Deslippe, from Victoria University of Wellington, is an expert in soil mycorrhizal fungi.

”Mycorrhizal fungi are a symbiosis, so two organisms living together. They’re a plant root – that’s the ‘rrhiza part’ - and the myco is the fungus part, and they are a soil fungus that lives in symbiosis with a plant root.”

Julie says that it’s a partnership: “the plant makes sugars by photosynthesis. It feeds that sugar to the fungi in exchange for soil nutrients and water.”

As well, she says that the fungi connect different trees, which communicate and exchange resources via the fungal network. Mycorrhizal fungi are a vital part of a healthy forest ecosystem, but Julie says they don’t know what fungi still exist in the some soils which has been grazed as rough pasture since the original forest was cleared.

She hopes that the few remaining native trees may have maintained a network of fungi that will help the next generations of trees.

iv.

Some lichens are useful sources as dyes, and potentially have medicinal properties as they are known to have antibiotic and

antibacterial properties.

v.

Excerpts:

<https://teara.govt.nz/en/shrublands/>

Shrublands:

Importance of shrublands Valuable ecosystems

Long despised as scrub weeds by farmers, native shrubs are slowly gaining acceptance as a valuable part of the landscape. Shrublands harbour a rich mix of native plants, animals and fungi. These vary around the country, and are mostly not well documented.

Invertebrates and fungi

The rich invertebrate life of native shrublands is slowly being revealed. In a small reserve in Central Otago, 280 different species (spiders, insects, crustaceans, millipedes, snails and worms) were found on and under 30 plants.

At least 700 species of native fungi are found in mānuka shrublands, where they live in a beneficial association with mānuka.

Birds and lizards

Open shrublands provide shelter and a nesting habitat for banded dotterels and the New Zealand pipit. New Zealand falcons hunt in shrub country, and green finches, hedge sparrows and brown creepers nest in subalpine shrubs. Kea feed on fruit and insects in subalpine scrub.

A number of skinks and geckos also inhabit shrublands. They eat small invertebrates, and seasonal fruits from the shrubs.

Lizards spread seeds in shrublands, especially those of coprosma fruits, a favourite food.

Beneficial effects of shrublands

On steep, erosion-prone soils, shrublands protect the land against slips.

Secondary shrublands, of both native and introduced plants,

provide shelter and act as a nursery for regenerating forest. They are an effective carbon store, holding around 15.5 tonnes of carbon per hectare. This increases to about 212 tonnes of carbon per hectare as the shrublands develop into mature forest. Carbon accumulation by mānuka is similar to that of fast-growing pine plantations.

Mānuka and kānuka are major sources of honey. Some mānuka honey with high antibacterial activity is used in a range of medical products.

#### Disappearing shrublands

There are no national regulations for the protection of shrublands, apart from those covered by the Resource Management Act. Between 1997 and 2002, 12,415 hectares of native shrubland and scrub were cleared for pasture or conversion to forestry.

5.

In November at the Glasgow Summit, COP 26, world leaders, including New Zealand, announced a commitment to halting and reversing deforestation and to reverse Biodiversity Loss by 2030 for Sustainable Development.

See attached:

Leaders' pledge for nature. United to Reverse Biodiversity Loss by 2030 for Sustainable Development  
COP 26 2021 deforestation signitures copy.

6.

The holistic ecological health of the land, water, sea and all living things are inextricably inter-connected with the well-being of mana whenua, New Zealanders and the whole world. We have only one planet and New Zealand has many unique species, found nowhere else in the world.

We must protect, preserve, conserve, and restore our indigenous species and ecosystems.



Remember  
submissions  
close on Friday  
6 August 2021  
at 5pm.

# Proposed District Plan submission form

Clause 6 of the First Schedule, Resource Management Act 1991.

Feel free to add more pages to your submission to provide a fuller response.

To: Central Hawke's Bay District Council			
<b>1. Submitter details</b>			
Full Name	Last <b>BAYLISS</b>	First <b>KATHRYN</b>	
Company/Organisation (if applicable)			
Contact Person (if different)			
Email Address	<b>Kall@xtia.co.nz</b>		
Address	<b>116 Maharakeke Road RD4 Waipawa</b>	Postcode <b>4281</b>	
Phone	Mobile	Home <b>06 858 9900</b>	Work
<b>2.</b> This is a submission on the Proposed District Plan for Central Hawke's Bay			
<b>3.</b> <input type="checkbox"/> I could <input checked="" type="checkbox"/> I could not – gain an advantage in trade competition through this submission (Please tick relevant box)			
If you could gain an advantage in trade competition through this submission please complete point 4 below:			
<b>4.</b> <input type="checkbox"/> I am <input type="checkbox"/> I am not – directly affected by an effect of the subject matter of the submission that:			
(a) adversely affects the environment; and (b) does not relate to trade competition or the effects of trade competition. (Please tick relevant box if applicable)			
Note: If you are a person who could gain an advantage in trade competition through the submission, your right to make a submission may be limited by clause 6(4) of Part 1 of Schedule 1 of the Resource Management Act 1991.			
<b>5.</b> <input type="checkbox"/> I wish <input checked="" type="checkbox"/> I do not wish – to be heard in support of my submission in person (Please tick relevant box)			
<b>6.</b> <input type="checkbox"/> I will <input checked="" type="checkbox"/> I will not – consider presenting a joint case with other submitters, who make a similar submission, at a hearing. (Please tick relevant box)			
<b>7.</b> Do you wish to present your submission via Zoom? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No			
<b>8.</b> Please complete section below (insert additional boxes per provision you are submitting on):			
The specific provision of the plan that my submission relates to:			
<b>see next pages</b>			
Do you: <input type="checkbox"/> Support <input type="checkbox"/> Oppose <input type="checkbox"/> Amend (Please tick relevant box)			
What decision are you seeking from Council?			
Reasons:			
<b>see next pages</b>			
Please note: All submissions will be treated as public documents and will be made available on Council's website. However, you may request that your contact details (but not your name) be withheld. If you want your contact details withheld, please let us know by ticking this box. <input checked="" type="checkbox"/>			



The specific provision of the plan that my submission relates to is  
① Pages NFL-4 and NFL 10, Policy NFL-P5 and principal ~~Reasons~~ <sup>Reasons</sup> about the Makaroro Gorge (ONF-4) 2<sup>nd</sup> paragraph on page NFL 10

I oppose both the policy NFL-P5 and principal reasons given for the water storage within ONF-4 (Makaroro Gorge). I am seeking Council to delete them both.

My reasons are:

The water storage within ONF-4 Makaroro Gorge is an illegal dam.

The Board of Inquiry also found "that there was conjecture about whether the predicted social effects arising from the Ruataniwha Water Storage Scheme (RWSS) will occur" and "the economic outcomes might not be assured."

The information for the RWSS is outdated, speculative and conjecture. Much has changed since it was done.

More recent reports have said any smaller legal water storage facility on the same site is uneconomical and the site is unsuited to smaller volumes (see August 2020 Tonkin + Taylor CHB Water Security Project - Stage 1, Water Storage Options Assessment)

Costs have increased, it is difficult to get workers, and many people are realising the importance of caring for the natural environment.

In Hawkes Bay it has often been proven when irrigation water supplies are available corporate and industrial farmers take over family farms and there are negative social effects. There has been an increase in migrant labour and seasonal casual workers. School roles have fallen. With the change in farm ownership there can be conflicts with new farmers and their different approaches to farming. Automation for many jobs will increase in future.

Most economic reports have not taken into consideration the productivity benefits of conservation biodiversity and environmental outcomes of not proceeding with the RWSS. Social benefits of improved water quality and quantity, less land use intensification, a ~~more~~ more natural environment to live in could be more benefit compared to a limited number of people who might get a financial benefit from water storage in the Makaroro Gorge.

The specific provision of the plan my submission relates to:

② ECO-R2, R3, R4, R5, R6, pages ECO-7, 8, 9, 10, 11 ~~and~~  
Clearance of indigenous vegetation.

I ~~do~~ oppose them.

I am seeking Council to prohibit clearance of indigenous vegetation except for ECO-R3, 1b. (pages ECO-8, ECO-9). Trimming should be discretionary and limited also to ECO-R3 1b.

The reasons:

Manuka and Kanuka species should be given the same protection and status as other indigenous vegetation species. They are important indigenous colonising and nurse plants that grow quickly and provide ideal conditions for the establishment of other indigenous trees and shrubs.

Indigenous vegetation that has naturally re-grown is usually more adapted to the area than ~~planted~~ <sup>planted</sup> by people. They help increase the biodiversity.

If allowing clearance of a limited area and size each year, the cumulative extent over years can be substantial. As there is only a small amount of remaining indigenous cover in CHB all must be protected.

Small, young sizes of indigenous vegetation needs to be allowed to grow and mature as it will eventually replace older vegetation that naturally dies.

ECO-P4 (page ECO-5) 2. should include all water bodies.

We are encouraged by government, and MBRC, who provide some funding, to plant trees to help control erosion, reduce climate change, enhance our natural environment and help people connect with nature to improve their wellbeing. It has negative effects to allow any indigenous vegetation to be cleared. It affects the environment in many ways. Protecting naturally re-grown indigenous vegetation can save time, labour and money.

② The provision of the plan that my submission relates to is EW P8 - P10, Earthworks - hydrocarbon extraction activities; pages EW-1 to EW-19, all references to hydrocarbon activities.

The decision I am seeking from Council is to make hydrocarbons, fossil fuels including coal, gas and oil<sup>mining</sup> activities prohibited.

These produce greenhouse gas emissions and contribute to climate change. Everyone is trying to reduce greenhouse gas emissions and stopping reliance on them.

Oil, gas and coal can have huge negatives on our environment and pose a big risk to our water, soils and air. Extraction ~~can~~ increase earthquake risks.

Prospecting, exploration, extraction and use of fossil fuels including hydrocarbons, gas, oil and coal can have a negative effect on human and animal health and wellbeing.

Excerpts from:

Climate change and agriculture: **Understanding the biological greenhouse gases**

Dr Jan Wright. **Parliamentary Commissioner for the Environment October 2016**

Full Report available at: [www.pce.parliament.nz](http://www.pce.parliament.nz)

Chapter 9 – How can trees help us?

Chapters 5 through 8 have looked at the potential for reducing the methane and nitrous oxide emissions from agriculture directly using a variety of technologies. Using trees to offset emissions is another approach that can be considered. It seems particularly appropriate as a way of addressing biological emissions since forestry and farming are different uses of land. Farmers already plant trees for many purposes – for shelter, for timber, to control erosion, and to protect waterways. But can more trees help offset the biological emissions from agriculture? This question is explored in this chapter. As trees grow, they take carbon dioxide out of the atmosphere. The carbon is stored in the trees and oxygen is released into the atmosphere through the process of photosynthesis. About half the dry weight of a tree is carbon. Each tonne of carbon stored in a tree means that almost four tonnes of carbon dioxide has been taken out of the air. By storing carbon, trees effectively store carbon dioxide.

In the first section, the possibility of allowing native forests to regenerate on marginal land is considered. The areas of native forest that would offset the biological emissions from sheep, beef, and dairy farms are estimated. Such forests accumulate carbon slowly but steadily for a long time.

### **9.1 Regenerating native forests**

The mature podocarp and beech forests of New Zealand have an enormous amount of carbon stored within their wood. If all these forests were to burn down, the carbon dioxide released into the atmosphere would be about 75 times as much as the country's total annual greenhouse gas emissions.

These mature forests are, on average, neither losing nor gaining carbon. However, regenerating native forests are slowly accumulating and storing carbon dioxide.

The reestablishment of a native forest commonly begins with the 'pioneer' shrubs of mānuka and kānuka because they thrive in cleared land. These shelter tree seedlings. The mānuka starts to die after about 40 years, opening up space for trees such as tawa and kāmahī. Later the giant podocarps – rimu, totara, and kahikatea – emerge through the canopy.

Large areas of New Zealand were once covered in podocarp forest. Many trees were felled for timber, and much of the remaining forest was cleared and burned to make way for agriculture. Some of the cleared land has become 'marginal' for agriculture, and if fenced off, could slowly begin to regenerate into podocarp forest.

**Figure 9.1 Regenerating mānuka invading pasture on a North Island hill country sheep farm. The scrub seen in the background of the picture has reverted from pasture land over the last two decades.**



How large would a regenerating podocarp forest need to be to offset the biological emissions from sheep, beef, and dairy farms?

The accumulation rate shown over the first fifty years is much faster than over the second fifty years. As the mānuka, and later the kānuka, die off, the accumulation rate slows because the other species coming through the canopy grow very slowly at first.

Table 9.1 shows the areas of regenerating podocarp forest that would offset the biological emissions from sheep, beef, and dairy farms.

The first column shows the methane and nitrous oxide emitted annually by livestock – 100 sheep, 100 beef cattle, and 100 dairy cattle – expressed in the equivalent amount of carbon dioxide.

The second column shows the area of regenerating native forest that would be needed to offset these emissions every year for fifty years.

**Table 9.1 Offsetting biological emissions from livestock using regenerating native forest.**

	Tonnes of CO <sub>2</sub> -eq per year from 100 animals	Hectares of forest needed to offset biological emissions
Sheep	38	6
Beef	179	28
Dairy	273	42

Table 9.1 shows the areas of regenerating podocarp forest that would offset the biological emissions from sheep, beef, and dairy farms.

The first column shows the methane and nitrous oxide emitted annually by livestock – 100 sheep, 100 beef cattle, and 100 dairy cattle – expressed in the equivalent amount of carbon dioxide.

The second column shows the area of regenerating native forest that would be needed to offset these emissions every year for fifty years.



Source: Virtual Oceania

**Figure 9.3 Mānuka trees die off at about 40 years old, the canopy opens, and other native tree species take over.**

### 9.3 How much can trees help us?

#### *Regenerating native forest*

There are large areas of low productivity grassland mostly in the North Island that contain seeds of native shrubs and trees. These can potentially revert to podocarp and broadleaf forest. In many places, the land would initially be covered with gorse, but this spiny invasive legume can act as a nursery for native shrubs and trees, sheltering them from the wind and supplying them with nitrogen.

Enabling native forest to regenerate through fencing off marginal farmland does much more than just sucking carbon dioxide out of the air. Enormous amounts of topsoil have been lost as erosion has followed the clearing of forest on unstable hill country. This has led to layers of sediment building up on the beds of streams and rivers. The result has been a loss of biodiversity on both land and in freshwater, along with falling agricultural productivity. Regenerating forest can arrest and begin to reverse this decline.

Building and maintaining fences would be a significant cost. There would also be a loss of grazing but, on the other hand, there would be a reduction in the time-consuming work of keeping pasture free of scrub. Then there is the potential for beekeeping – the price of mānuka honey has grown rapidly over recent years.

The cost of establishing a native forest will be much greater if seedlings must be planted and pests controlled. It is not just possums that are a problem. Deer and goats browse on seedlings and saplings, and also alter the composition of the forest and thus the amount of carbon stored.

How much marginal agricultural land has the potential to revert to shrubland and native forest? Various analyses have suggested that at least a million hectares of land would fall into this category.

Allowing a million hectares of marginal hill country to revert to scrub could capture the equivalent of about 17% of all the biological methane and nitrous oxide currently emitted each year for 50 years. This carbon store would continue to grow for hundreds of years.

### 10.3 Mitigation and offsetting

#### *Offsetting with carbon forests*

A very different approach to dealing with biological emissions is to use trees to soak up and store carbon dioxide. Forests can be used for offsetting – taking carbon dioxide out of the atmosphere to compensate for the biological emissions entering the atmosphere.

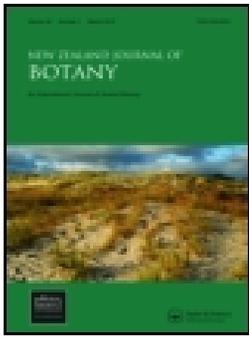
Establishing carbon forests does not rely on technological breakthroughs. Carbon

forests are already included in New Zealand's Emissions Trading Scheme, but much more can be done.

For instance, a hill country sheep farmer might fence off higher altitude land and leave the mānuka scrub to begin the slow steady recovery into mature podocarp forest, with all the accompanying benefits of slowing erosion, keeping sediment out of waterways, ameliorating flooding, and providing habitat for native birds and other creatures.

During this investigation, it was found that the biological emissions of 100 sheep could be offset indefinitely by about 6 hectares of marginal land left to regenerate into native forest. For 100 beef cattle, about 28 hectares would be required, and for 100 dairy cows, about 42 hectares.

It has been estimated that at least a million hectares of marginal land could be left to regenerate back into native forest. This would offset about 17% of all the biological methane and nitrous oxide currently emitted each year from agriculture for the indefinite future.



## A review of *Leptospermum scoparium* (Myrtaceae) in New Zealand

J. M. C. Stephens , P. C. Molan & B. D. Clarkson

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## A review of *Leptospermum scoparium* (Myrtaceae) in New Zealand

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**Abstract** Information about *Leptospermum scoparium* (Myrtaceae), the most widespread and important New Zealand indigenous shrub species, is reviewed. *L. scoparium* is a variable species, requiring more study of the genetically based differences between New Zealand populations and the affinity of these populations to Australian populations and other closely allied Australian species. Improved understanding of the species' variation will assist both its conservation roles and economic uses, and the need to sustain genetically distinct varieties is emphasised. Ecologically, the species has a dominant role in infertile and poorly drained environments, and a wider occurrence as a seral shrub species in successions to forest where it may be regarded as a woody weed of pasture or a useful species for erosion control, carbon sequestration, and vegetation restoration. The main economic products derived from the species are ornamental shrubs, essential oils, and honey. The species' development as an ornamental plant and further definition of the pharmacologically active components are recommended as priority areas for research.

**Keywords** Myrtaceae; *Leptospermum scoparium*; manuka; tea tree; New Zealand; taxonomy; chemotaxonomy; ecology; history; ornamental; essential oils; honey; pharmacology

### INTRODUCTION

Information about *Leptospermum scoparium* is spread throughout much literature. *L. scoparium* is the most widespread and important indigenous shrub species in New Zealand, and has probably undergone the most varied development as an economic plant in the indigenous flora. Bibliographies compiled by Orwin (1974) and Williams (1981) provide background material to this review. Whilst all material that refers to *L. scoparium* in passing has not been included, each section draws upon the principal publications. Chemical control aspects are not included.

The taxonomy, morphology, distribution, habitats and plant communities, and other biological associations in which it occurs are considered here, along with its historic and current uses as a source of essential oils and honey, and for ornamental shrub development. The majority of early research considered the ecological position of *L. scoparium*, either as a dominant species where environmental stress is extreme, or as a seral species in disturbed habitats where the species was recognised as a significant weed of recently cleared forest for pasture development. Recognition of the genetic and phenotypic variation exhibited by the species led to studies isolating various components of this diversity, ranging from morphological to chemotaxonomic treatments. Commercial development as an ornamental shrub and the identification of medicinal essential oil and honey components have motivated most of the recent research, and a collation of this material is warranted.

We consider it timely to review the biology of *L. scoparium* as a basis for further economic development of the species and conservation of genetic variation.

## BIOLOGY AND ECOLOGY

### Taxonomy, morphology, anatomy, cytology

*Leptospermum scoparium* J.R. et G.Forst. (manuka, kahikatoa, tea tree, red tea tree) is a member of the Myrtaceae. This family contains at least 133 genera and more than 3800 species, and has evolutionary centres in Australia, Southeast Asia, and Central and temperate South America. Myrtaceae are characterised by a half-inferior to inferior ovary, usually numerous stamens, entire leaves containing oil glands, internal phloem, and vestured pits on the xylem vessels (Wilson et al. 2001).

Until recently Myrtaceae was divided into two subfamilies, the capsular Leptospermoideae and the fleshy-fruited Myrtoideae. An extensive review of the Myrtaceae inflorescence structure confirmed this division; the Leptospermoideae contained seven alliances including the *Leptospermum* alliance, which was further subdivided into the *Leptospermum* and *Calothamnus* suballiances (Briggs & Johnson 1979). However, cladistic analysis of morphological and anatomical characters concluded that the subfamilies should be discarded, as the fleshy-fruited *Acmena* alliance did not group within the Myrtoideae subfamily (Johnson & Briggs 1984). A cladistic re-evaluation of non-molecular characters confirmed a high level of homoplasy within Myrtaceae and limited support for any clade (Wilson et al. 1994).

Molecular analysis placed further doubt on the traditional taxonomic groupings. Sequences of the chloroplast *matK* gene analysed in association with nonmolecular data revealed that the *Leptospermum* alliance was polyphyletic and, thus, an invalid taxonomic concept (Wilson et al. 2001). The sequencing of two chloroplast regions for 31 species within the *Leptospermum* suballiance revealed a monophyletic grouping of eight genera and the suballiance was considered a valid taxonomic unit (O'Brien et al. 2000). However, the same study concluded that *Leptospermum* is polyphyletic and should be divided into at least four genera: the persistent-fruit group, the East Australian non-persistent-fruit and West Australian non-persistent-fruit groups, and *Leptospermum spinescens* separated as a fourth genus. *L. scoparium* was not included in this analysis but its fruit morphology allies it to the persistent-fruit group.

Analysis of leaf anatomy of 40 species of *Leptospermum* showed that *L. scoparium* has the typical xeromorphic structure of the genus (Johnson 1980). The wood anatomy (Johnson 1984; Patel 1994) and the pollen morphology (McIntyre 1963)

of *L. scoparium* also support the species genus classification.

A comprehensive taxonomic revision of the genus *Leptospermum* listed 79 species (Thompson 1989), which has been increased to 83 with later additions (Dawson 1997a). *L. scoparium* is one of 13 species included in the *Leptospermum myrtifolium* subgroup, the defining characteristics of which are deciduous sepals and persistent strongly wooded fruit-valves (Thompson 1989). The Australian species within this sub-group are extremely difficult to define; *L. continentale* and *L. rotundifolium* were recently elevated by Thompson (1989) from *L. scoparium* varieties to species rank. The species *L. juniperinum* and *L. squarrosus* have both been recorded as varieties of *L. scoparium* (Thompson 1989), and the endemic Tasmanian *L. scoparium* var. *eximium* could be considered to warrant species status, displaying lignotuber development which is not found in New Zealand's *L. scoparium* (Bond et al. 2004).

Initially three species of *Leptospermum* were recorded as endemic to New Zealand; the widespread *Leptospermum scoparium* and *L. ericoides*, and *L. sinclairii* restricted to Great Barrier Island (Allan 1961). Revision of *Leptospermum* led to the transfer of *L. ericoides* to *Kunzea* as *K. ericoides* (A.Rich.) J.Thompson (Thompson 1983). *L. sinclairii* was included in synonymy to this species, and a new name combination of *K. sinclairii* (Kirk) W.Harris was later published without supporting material (Connor & Edgar 1987). Accordingly, *L. scoparium* is now considered to be the only indigenous member of *Leptospermum* in New Zealand. The species is not endemic to New Zealand as indicated by Allan (1961), as it also occurs naturally in mainland Australia from the southern coast of New South Wales to western Victoria and is widespread in Tasmania (Thompson 1989).

The time of arrival of *L. scoparium* in New Zealand is uncertain. *Leptospermum* pollen has been dated to the Paleocene (Fleming 1975), though the representatives in the upper Cretaceous and older Tertiary beds should be interpreted to represent type pollen and not individual species (Couper 1953, 1960). Thompson (1989) suggested that *Leptospermum* may have originated in the dry Miocene conditions in Australia and that *L. scoparium* dispersal to New Zealand occurred relatively recently, as the species is not a primitive *Leptospermum* and cannot have been present earlier in New Zealand. Wardle (1991) recorded *L. scoparium* as the only New Zealand species to release seed overwhelmingly in concert after fire, a serotinous feature common in the

Australian flora. Further evidence for the recent evolution of the genus *Leptospermum* is provided by incomplete sterility barriers and the number of putative hybrids in Australia (Thompson 1989). Nevertheless only three Australian species are tetraploid, indicating that polyploidy has not been a major influence at the evolutionary centre of the genus (Dawson 1990). A number of defined *Leptospermum* hybrids exist (Harris 2000), and one wild flowering intergeneric hybrid has been reported, *Kunzea sinclairii* × *L. scoparium* (Harris et al. 1992). Intergenic hybrids have also been produced from controlled crosses, but neither the *Kunzea sinclairii* × *L. scoparium* nor the *Kunzea* aff. *ericoides* × *L. scoparium* hybrids had flowered after five years (de Lange & Murray 2004).

The following description is drawn from those given by Allan (1961) and Thompson (1989). *L. scoparium* is a variable shrub or small tree usually about 2 m tall but occasionally reaching 4 m or more, and dwarfed in exposed situations. Bark is close and firm, with young stems bearing a silky pubescence but soon becoming glabrous. Leaves are highly variable both in size and shape, 7–20 × 2–6 mm, ranging from broadly elliptical to lanceolate, coriaceous with incurved margins, rigid, acuminate pungent apex, petiole, young leaves glabrous. Flowers are white or rarely pink or red, axillary or occasionally terminal on branchlets, usually solitary and sessile, 8–12 mm diam., flowering Oct–Feb. Hypanthium is usually glabrous with a distinct pedicel, expanded upper and broadly turbinate. Sepals are deciduous, oblong to broadly deltoid. Petals are 5 × 4–7 mm suborbicular and slightly clawed. Stamens occur in bunches of 5–7(–9), 2.5–3.5 mm long. Style is inset with a large stigma, often reduced or absent. Ovary is 5-locular, each ovary containing about 100 ovules. Fruits are woody persistent 5-valved capsules 6–9 mm diam., distinctly exerted beyond receptacle rim. Mature seeds are 2–3.5 mm long, irregularly narrowly linear-cuneiform or sigmoid, curved, striate.

*Leptospermum scoparium* is an andromonoecious species; however, the variation in percentage of perfect flowers is mostly environmentally produced (Primack & Lloyd 1980). Overall control of flowering is determined by temperature and day-length. *L. scoparium* flowering is initially activated by a long-day flowering cue, although bud development is restrained by cool temperatures throughout winter leading to spring flowering when the temperature restraint is lifted (Zieslin & Gottesman 1986).

Throughout New Zealand *L. scoparium* is normally diploid with 22 chromosomes (Dawson 1987, 1990),

but two triploid and one tetraploid cultivars have been described (Dawson 1990) and wild aneuploids have been recorded (P. de Lange pers. comm.).

### Intraspecific variation

Cockayne (1919, p. 73) wrote “*Leptospermum scoparium* ... presents a diversity of forms which are seemingly impossible to classify. Some, it is true, are distinct races, but most are probably unfixed hybrids between races not yet defined by the plant-classifier”. This statement fairly represents the variability displayed by this species. In attempts to classify the species several wild varieties have been described in New Zealand. Cheeseman (1925) agreed with Cockayne (1919) and listed one species, disputing the earlier classification of four varieties by Hooker (1867). Allan (1961) described two varieties, mentioned a further four, and suggested that the forms may either result from habitat-modification or be genetically determined. The uncertainty regarding the cause of *L. scoparium* variability is reinforced in the genus revision (Thompson 1989). Webb et al. (1988) discussed two varieties of *L. scoparium*, var. *incanum* and var. *linifolium*, and also listed the naturalised Australian species *L. laevigatum* as occurring in New Zealand.

*Leptospermum scoparium* var. *scoparium* was listed by Allan (1961) to represent the species description and is considered widespread. *L. scoparium* var. *incanum* (Cheeseman 1925; Allan 1961; Webb et al. 1988) has lanceolate-linear leaves c. 8 mm long, rose-tinted petals, and is common especially in the far north of the North Auckland Botanical District. *L. scoparium* var. *prostratum* (Allan 1961) has a prostrate growth form and characteristically appears on mountains. *L. scoparium* var. *myrtifolium* (Allan 1961) has smaller more ovate recurved leaves and is widespread. *L. scoparium* var. *parvum* (Allan 1961) is recorded from the Wellington District, and is a small shrub with very small flowers and hairy leathery foliage. *L. scoparium* var. *linifolium* (Allan 1961) has linear-lanceolate leaves and is also recorded as widespread. Webb et al. (1988) placed *L. scoparium* var. *incanum* and *L. scoparium* var. *linifolium* together.

Variable morphological characteristics in *L. scoparium* in New Zealand have been examined. Yin et al. (1984) studied variation of *L. scoparium* using leaf material from 182 herbarium specimens covering most of the natural range of the species, a common garden experiment, and a field analysis of natural populations. The herbarium specimens revealed significant correlations of leaf morphology

with latitude, distance from coast, and annual and winter temperatures. Their common garden experiment established that leaf dimensions and plant morphology had a significant genotypic basis (Yin et al. 1984). Measurement of seven morphological characteristics of the populations grown in common conditions by Yin et al. (1984) also revealed considerable within-population genetic variability (Wilson et al. 1991). Genotypic variation has also been shown for growth form (Harris 1994), leaf variation (Harris 2002), tolerance of soil acidity (Berninger 1992), soil fertility response (Lyon et al. 1971), root anatomy (Cook et al. 1980), and freezing resistance (Greer et al. 1991; Decourtye & Harris 1992). Genotypic variance within a population in growth habit, leaf size, leaf density, and stem and foliage colour were revealed when a population was grown under common conditions by Porter et al. (1998). The flowering times within a population, among adjacent populations and geographically widely separated populations, and between seasons are highly variable (Primack 1980). This variability also has a genetic component; both age at first flowering and period of flowering differed in a common garden experiment (Yin et al. 1984).

The ability of the species to respond phenotypically to different environments was shown when Burrell (1965) transplanted seedlings of *L. scoparium* from Central Otago to Dunedin, where they immediately produced larger leaves but remained typical of the ecotype. Another example of the species' phenotypic plasticity was provided by Gaynor (1979), who showed that branching height in the field was correlated with soil depth.

Burrell (1965) noted that *L. scoparium* in Central Otago retained intact capsules until opening was induced by either drought or fire, and later studies have shown that the rate of capsule splitting differs between populations. Genetic control of capsule splitting was confirmed in a common garden experiment, and it was hypothesised that the difference between New Zealand populations had arisen from rapid selection by regular fire disturbance since the arrival of people (Harris 2002). However, a South Island field study showed that population differences of capsule splitting related to a much longer history of fire exposure in the regions displaying serotiny (Bond et al. 2004).

### Distribution, habitats, and plant associations

Although the time of arrival of *L. scoparium* in New Zealand is uncertain, current opinion suggests a relatively recent dispersal from Australia (Thompson

1989). The distribution within New Zealand would have been restricted until the land clearance associated with human settlement vastly increased the area of low-nutrient environments to which the species was adapted in Australia (Thompson 1989).

*Leptospermum scoparium* has two main ecological roles in New Zealand vegetation: permanent dominance of extreme environments or as a seral species (Burrows 1973; Wardle 1991). Permanent dominance occurs on sites that are unfavourable for the development of climax forest as they are too wet, dry, cold, exposed, infertile, or unstable. The seral role is on disturbed sites, where *L. scoparium* is an early woody species in the succession to forest. This role has been greatly extended by human disturbance (Molloy 1975; Wardle 1991).

Five vegetation communities, the Northland gumlands, Waikato wetlands, East Coast regenerative seral scrub, North Island Volcanic Plateau heathlands, and Westland pakihi swamps, which contain *L. scoparium* as a major component and occupy large areas, are considered in detail. The common woody dicotyledonous members of these *L. scoparium*-dominated communities are listed in Table 1.

Soils too wet and infertile for the establishment of climax forest are widespread throughout New Zealand, ranging from gumland in Northland to mire in Southland, upon all of which *L. scoparium* dominates (Burrows et al. 1979). The Northland gumlands are typically leached infertile clays with perched water tables and sand podzols sustaining *L. scoparium* heathland (Esler & Rumball 1975; Beever 1988; Enright 1989; Wardle 1991). Whilst much of this land has been cleared and drained for farmland, significant remnants remain. The 16000 year old Ahipara plateau (Wardle 1991) and the Ngarura swamp in the Waipoua forest (Burns & Leathwick 1996) are examples of self-maintaining *L. scoparium* heathland in this region. Studies of the far north (Enright 1989), Waipoua Forest heathlands (Burns & Leathwick 1996), and heath near Kaikohe (Esler & Rumball 1975) listed 10 woody dicotyledonous species in two or more reports. Two of these 10 species are invasive introductions, *Hakea sericea* and *Ulex europaeus*; the remaining eight form the endemic community in this environment (Table 1).

Waikato oligotrophic lowland mires exhibit a range of infertility yet all support permanent *L. scoparium* populations (Burrows et al. 1979; Wardle 1991). A comparison of three of these Waikato environments, the extreme Kopuatai bog (Irving et al. 1984), the intermediary Moanatuatua bog (Burrows et al. 1979; Clarkson 1997), and the relatively

**Table 1** Principal associated woody dicotyledonous species in five *Leptospermum scoparium*-dominated environments. Northland gumland: <sup>1</sup>Enright 1989; <sup>2</sup>Burns & Leatherick 1996; <sup>3</sup>Estler & Rumball 1975; <sup>4</sup>Burrows et al. 1979; Waikato wetland: <sup>5</sup>Irving et al. 1984; <sup>6</sup>Burrows et al. 1979; <sup>7</sup>Clarkson 1997; East Coast serral shrub: <sup>8</sup>Clarkson et al. 1986; <sup>9</sup>Regnier et al. 1988; <sup>10</sup>Clarkson & Clarkson 1991; <sup>11</sup>Whaley et al. 2001; Volcanic Plateau heathland: <sup>12</sup>Rogers & Leatherick 1994; <sup>13</sup>Atkinson 1981; <sup>14</sup>McQueen 1961; <sup>15</sup>Leathwick 1987; <sup>16</sup>Clarkson 1984; Westland pakihī: <sup>17</sup>Rigg 1962; <sup>18</sup>Burrows et al. 1979; <sup>19</sup>Mark & Smith 1975; <sup>20</sup>Norton 1989.

Northland gumland	Waikato wetland	East Coast serral scrub	Volcanic Plateau heathland	Westland pakihī
<i>Dracophyllum lessonianium</i> <sup>1,2,3,4</sup>	<i>Epacris pauciflora</i> <sup>5,6,7</sup>	<i>Coprosma rhannoides</i> <sup>8,10</sup>	<i>Dracophyllum longifolium</i> <sup>12,13</sup>	* <i>Dracophyllum</i> spp. <sup>17,18,19,20</sup>
<i>Epacris pauciflora</i> <sup>1,2,3,4</sup>	<i>Erica lusitanica</i> <sup>8</sup>	<i>Coprosma robusta</i> <sup>8,9,11</sup>	<i>Dracophyllum subulatum</i> <sup>12,13,14,16</sup>	<i>Epacris pauciflora</i> <sup>17,18</sup>
<i>Leucopogon fasciculatus</i> <sup>1,2,3,4</sup>	<i>Salix cinerea</i> <sup>5,7</sup>	<i>Cortaria arborea</i> <sup>8,9,11</sup>	<i>Kunzea ericoides</i> <sup>12,13,16</sup>	<i>Metrosideros umbellata</i> <sup>18,19</sup>
<i>Myrsine australis</i> <sup>1,2</sup>		<i>Cyathodes juniperina</i> <sup>10,11</sup>	<i>Leucopogon fasciculatus</i> <sup>13,15,16</sup>	<i>Weinmannia racemosa</i> <sup>18,19,20</sup>
<i>Pimelea prostrata</i> <sup>1,3</sup>		<i>Hebe stricta</i> <sup>8,11</sup>		
<i>Pomaderris kumeraho</i> <sup>1,3,4</sup>		<i>Kunzea ericoides</i> <sup>8,9,10,11</sup>	<i>Calluna vulgaris</i> <sup>13</sup>	<i>Ulex europaeus</i> <sup>17</sup>
<i>Pomaderris phyllifolia</i> <sup>1,3</sup>		<i>Pittosporum ralphii</i> <sup>9,11</sup>	<i>Erica lusitanica</i> <sup>14,15</sup>	
<i>Weinmannia silvicola</i> <sup>2,3</sup>		<i>Pittosporum tenuifolium</i> <sup>8,9,10</sup>		
		<i>Pseudopanax arboreus</i> <sup>8,9</sup>		
<i>Hakea sericea</i> <sup>1,3,4</sup>		<i>Weinmannia racemosa</i> <sup>8,11</sup>		
<i>Ulex europaeus</i> <sup>1,3</sup>				
		<i>Ulex europaeus</i> <sup>8</sup>		

\* *Dracophyllum* spp. represents *D. longifolium* and *D. palustre* which are possibly the same taxon (Allan 1961, p. 533).

more fertile Whangamarino fen (Clarkson 1997), reveals five other woody dicotyledons present with *L. scoparium*. Of these, the endemic species *Epacris pauciflora* was noted in every report and the introduced *Salix cinerea* in two. *Erica lusitanica* occurred only at Kopuatai, but was included because of its invasive abilities (Table 1).

*Leptospermum scoparium* is prevalent on infertile leached Westland pakihī soils, and a number of widespread communities have been studied in Westland in the northern area (Rigg 1962; Burrows et al. 1979; Norton 1989), the central area (Burrows et al. 1979), and the southern reaches (Mark & Smith 1975). The communities differ according to latitude yet a common theme is found. One woody dicotyledonous species was always recorded with *L. scoparium* in the northern area, five species in the southern study bordering with forest, and in central Westland the reported species were the same as those found in both the other areas. Thus, a typical vegetation community of Westland pakihī contains only 4 of the 19 endemic species found in association with *L. scoparium*, and the exceptionally invasive *Ulex europaeus* was included despite being recorded on better-drained ridges in one report (Table 1). However, *L. scoparium* dominance may be replaced by larger forest species in the pakihī areas provided fire is infrequent and the environment is not exceptionally infertile (Williams et al. 1990).

In south Westland (Wardle 1974) and Fiordland (Wardle et al. 1973) lowland swamps are prime habitats, and montane raised mires in Fiordland (Burrows & Dobson 1972; Mark et al. 1979) and Otago (Johnson et al. 1977) also carry *L. scoparium*. Following fire in a Southland bog, *L. scoparium* dominated the environment rapidly (Johnson 2001). In association with swamp-like environments *L. scoparium* dominates lake shorelines around the southern lakes where it survives temporary submergence (Johnson 1972; Mark et al. 1977; Robertson et al. 1991). In these conditions the species differentiates specialised aeration tissue, aerenchyma, in submerged roots allowing long-term dominance in waterlogged environments (Cook et al. 1980).

Areas too high and cold for the establishment of climax forest occur in both main islands (Wardle 1991). *L. scoparium* occurs above the tree line (Wardle 1963; Gibbs 1966) and on upland peat and gley soils of both main islands (Burrows et al. 1979), and is frequent on inhospitable sites at low and high altitude in south Westland (Burrows 1964; Wardle 1977) and Southland (Burrows 1964; Burrows et al. 1979), and in montane scrubland on Stewart Island

(Wells & Mark 1966). However, at high altitude in Otago growth is limited to warmer microclimates (Wilson et al. 1989). Comparison of the five studies of montane flora in the central North Island, the Rangipo Depression (Rogers & Leathwick 1994) and the volcanic slopes of Mt Tongariro (Atkinson 1981) at high altitude, and at lower altitude the widespread ignimbrite pumice plain near Tokoroa (McQueen 1961), the Waipapa Ecological Area (Leathwick 1987), and Pureora mountain mires (Clarkson 1984), demonstrates greater diversity as forest species return to more hospitable environments. Four endemic woody dicotyledonous species are noted as common throughout the region, and the invasive heathers *Calluna vulgaris* and *Erica lusitanica* were recorded at the higher and lower sites, respectively (Table 1).

In coastal environments throughout New Zealand *L. scoparium* and *K. ericoides* are found on areas too exposed for forest (Morton & Miller 1968; Molloy 1975). *L. scoparium* occurs on sites as diverse as the edge of mangrove swamps in the Auckland region (Wardle 1991), the Cape Reinga district in the far north (Wheeler 1963), Farewell Spit in Nelson (Burrows 1973), and the coastal cliff zones around southern Wairarapa and Wellington (Burrows 1973).

Areas too infertile for the establishment of forest overlap with the above categories, as the environments are the same. Oligotrophic mires and swamps, extreme coastal and altitudinal sites, and heavily leached soils have all been discussed. *L. scoparium* is also present in other situations: the geothermic heated environments of the central North Island (Wells & Whitton 1966; Given 1980), edaphically dry pumice in the central North Island (Elder 1962), and as a consistent understorey on poor gleyed soils in forested areas (Burrows 1973). *L. scoparium* is also tolerant of South Island ultramafic soils (Lyon et al. 1971; Lee et al. 1975, 1983; Lee 1992).

Natural unstable environments also lend themselves to colonisation by *L. scoparium*. Landslides in Fiordland forests are rapidly covered by *L. scoparium* in a seral role (Mark et al. 1964). *L. scoparium* establishes on braided river beds (Burrows 1973) and unconsolidated coastal deposits where it is a woody pioneer (Wardle 1991).

Soils too dry for climax forest vegetation present a more complicated picture. Typically these areas occur in the eastern rain shadow of the New Zealand mountain ranges (Wardle 1991). *L. scoparium* occurs as a dominant species in relatively higher rainfall areas of these regions, but becomes uncommon in dryer situations where *Kunzea ericoides* dominates (Wardle 1971, 1991). In Otago where

yearly rainfall is less than 650 mm, *K. ericoides* is more common, interspersed with *L. scoparium* on boggy land (Burrell 1965). Self perpetuation of *K. ericoides*/*L. scoparium* scrub occurs where broadleaf forest establishment is either prevented (Wardle 2001) or retarded by site conditions (Dobson 1979).

In contrast to the permanent *L. scoparium* populations, seral communities also exist and form a significant proportion of the species' modern range. *L. scoparium* is found in moist forested regions forming similarly aged stands in a nursery role for climax vegetation following fire or other disturbance (Burrows 1973; Payton et al. 1984) where it may persist for more than a century (Mark et al. 1989). The species also establishes easily in open undergrazed pasture (Grant 1967), and its presence in this situation indicates unsustainable clearance of forest or scrub to establish pasture (Bascand 1973). *L. scoparium* may be the initial woody pioneer on moderately fertile well-drained soil due to prodigious seed set and rapid germination and growth (Mohan et al. 1984a,b). The species has an overriding germination response to full light spectra coupled with an inhibition by far-red wavelengths typical of pioneer species on disturbed sites (Herron et al. 2000; McKay et al. 2002). *L. scoparium* seed does not exhibit dormancy, and the unshed seed in capsules is probably the main reservoir of seed as the soil seed bank is non-persistent (Mohan et al. 1984a). Accordingly, *L. scoparium* scrub regeneration and re-establishment, which has been a feature of New Zealand hill farming, can be avoided with suitable land management such as the fertilisation and retention of a heavy sward (Levy 1970). Communities of *L. scoparium* are not permanent in regions where the rainfall is adequate to allow the establishment of climax broadleaved forest (Esler & Astridge 1974; Wardle 1991), and replacement by *K. ericoides* and subsequent establishment of forest has been recorded in Canterbury and Otago (Burrows 1961; Molloy & Ives 1972; Dobson 1979; Allen et al. 1992), Kapiti Island (Esler 1967), and the Hauraki Gulf islands (Atkinson 1954; Bellingham 1955; Esler 1978). The East Coast region of the North Island provides an example of these communities where large areas of coastal and lowland hillsides are covered with dense seral scrub, established since forest clearance for pasture development. Three types of *L. scoparium* scrub were described in the Motu Ecological District by Clarkson et al. (1986): *L. scoparium*, *L. scoparium*/*Coprosma* spp./*Hebe* spp., and *L. scoparium*/*Kunzea ericoides* scrub. Generally the same

situation exists around the East Cape (Regnier et al. 1988; Clarkson & Clarkson 1991; Whaley et al. 2001). Ten endemic woody dicotyledons were recorded in two or more studies (Table 1). Most of these species are associated with regenerating forest expected in a seral *L. scoparium* environment. Whilst *Ulex europaeus* was only recorded in one study, distribution is widespread and this species is accordingly included.

Where forest on steep slopes has been cleared for pasture establishment the land is often prone to erosion. The value of *L. scoparium* as protective scrub is now recognised, as it provides rapid (Smale et al. 1997) and excellent protection from shallow landslides (Watson & O'Loughlin 1985), and the presence of mature stands assists erosion control (Bergin et al. 1995). *L. scoparium* foliage can intercept a significant amount of rainfall (Burke 1981), as much as 40–50% in a storm event (Aldridge & Jackson 1968). Together with soil binding by roots this rainfall interruption is effective in erosion control. Carbon accumulation by *L. scoparium* is rapid and similar to that of plantation forestry (Scott et al. 2000).

The variety of environments in which *L. scoparium* occurs indicates the species' wide ecological amplitude, and a large population of any one endemic woody dicotyledonous species is not found in association with *L. scoparium* throughout its entire range. *Epacris pauciflora* and *Dracophyllum* spp. are common on the infertile lowlands, the seral shrub community contains a selection of early successional forest species, and the montane environments carry a mixture of *Dracophyllum* spp. and hardier forest species.

The same situation is seen with the introduced shrubs. *Ulex europaeus*, *Cytisus scoparius*, and *Teline monspessulana* are widespread throughout New Zealand, particularly in scrubland on low fertility hill country, yet these species do not inhabit poorly drained environments in appreciable numbers (Roy et al. 1998). *Hakea sericea* and *H. salicifolia* are both common in wet lowland environments as far south as northern Westland (Roy et al. 1998), but neither is found on the East Coast. The introduced Ericaceae species remain locally distributed apart from *Erica lusitanica*, which is now widespread on low-fertility wet soils throughout New Zealand (Roy et al. 1998).

A number of direct plant associations also occur with *L. scoparium*. The rare non-green orchid *Gastrodia minor* shares mycorrhizae with *L. scoparium* along with other plant species and is distributed

throughout New Zealand (Wardle 1991). *L. scoparium* acts as a host for the widely distributed large-leaved mistletoe *Ileostylus micranthus* (Molloy 1975), but *I. micranthus* exhibits low host specificity and is most frequently found in association with *Coprosma* spp. (Patel 1991). The widespread parasitic dwarf leafless mistletoe *Korthalsella salicornioides* attaches preferentially to *Leptospermum* and *Kunzea* (Stevenson 1934), but is also found with other endemic species and has been recorded in association with introduced *Erica* spp. (Bannister 1989).

## INSECT ASSOCIATIONS

Insect associations may be divided into two sections: the species involved in the pollination of *L. scoparium* and the insect pests.

### Pollination

Much of New Zealand's insect-pollinated flora has inconspicuously coloured flowers, which has been historically attributed to the lack of specific insect associations (Godley 1979; Lloyd 1985; Wardle 1991). The small white flowers of *L. scoparium* are classified as open-access with a dish/bowl shape and, typical of this type, are visited by a range of insect pollinators (Newstrom & Robertson 2005). Heine (1937) recorded representatives from the orders Coleoptera and Diptera. A detailed study of montane *L. scoparium* visitors revealed a range of insects arriving in a structured pattern (Primack 1978). Open flowers were visited by large tachinid and calliphorid flies at dawn, followed by a great variety of small Diptera with increasing temperature. In fine weather indigenous Hymenoptera visited flowers from mid morning. The bees and flies ended visits in the late afternoon, and in the early evening in settled weather moths (Pylalidae, Geometridae, Noctuidae) and craneflies (Tipulidae) were recorded. Nocturnal moth visits have been noted (Newstrom & Robertson 2005). The introduced honey-bee (*Apis mellifera*) also collects both pollen and nectar (Butz Huryn 1995). These observations confirm the non-specific pollinators associated with *L. scoparium*.

### Insect pests

The principal insect pests associated with *L. scoparium* in New Zealand are the scale insects, order Homoptera. Of the 17 species listed by Hoy (1961), most are distributed throughout New Zealand at low levels of infestation. The three most commonly found species are the endemic *Coelostomidia wai-*

*roensis* and introduced *Eriococcus orariensis* and *E. leptospermi*. The condition commonly described as manuka blight is associated with infestation by the introduced insect species and the development of a covering of sooty mould on the resultant honeydew.

*Coelostomidia wairoensis* is distributed throughout the North Island and the northern and eastern South Island and is associated with *Capnodium elegans*, one of the fungi that produce the visually diagnostic sooty mould on the stems of infested plants. *C. wairoensis* has not been reported to kill *L. scoparium* (Hoy 1961). *Eriococcus orariensis*, also associated with *Capnodium* spp., is common throughout New Zealand but absent in wetter regions and the sub-alpine belt (Wardle 1991). *E. orariensis* was introduced involuntarily from Australia in the mid 20th century, where it does not cause widespread death of the principal host species *Leptospermum juniperinum* in the southern and eastern areas of the mainland or *L. scoparium* in Tasmania. Once introduced into New Zealand it was deliberately spread and brought about a rapid eradication of large areas of *L. scoparium*. The removal of plant nutrients by the scale insect weakens the plants so that they are unable to survive environmental stress, and reduced photosynthetic efficiency may result from the covering of foliage by the sooty mould (Hoy 1961). The virulence of *E. orariensis* has been significantly reduced by the subsequent spread of the entomogenous fungus *Myriangiium thwaitesii*, and the revival of *L. scoparium* has been as spectacular as the initial decline (Hoy 1961). However, there is no record of resistant forms of *L. scoparium* in the literature. This disease complex does not affect the extensive cultivar plantings in the British Isles, as the primary pest *Eriococcus orariensis* has not been introduced (Dawson 1997b). *Eriococcus leptospermi*, often found together with *E. orariensis* throughout New Zealand, inhabits the bark surface towards the stem tips. Heavy infestation does not lead to plant death and *E. leptospermi* appears to be immune to *M. thwaitesii* (Hoy 1961).

Manuka beetles (*Pyronota* spp.) are also widespread, often found on light sandy montane soils associated with grassland on forest margins. These species appear to be non-specific feeders, often preferring grass root material to *L. scoparium* (Thomson et al. 1979), and may have a role in pollination (Heine 1937). The leaf-feeding manuka moth (*Declana floccose*) is also common, and other widespread insect pests are webworm (*Heliothibes atychioides*), the wood-boring larvae of the longhorn

beetle (*Ochrocodus huttoni*) and the gall-forming mite (*Aceria manukae*) (Molloy 1975), and the introduced wood-borer (*Amasa truncates*) (Brockerhoff & Bain 2000).

## FUNGAL ASSOCIATIONS

Many fungi have been noted in association with *L. scoparium*; but published records are far from comprehensive. A search of the New Zealand Fungal Herbarium database ([www.landcareresearch.co.nz/research/biodiversity/fungiprogl/](http://www.landcareresearch.co.nz/research/biodiversity/fungiprogl/)) revealed 699 *L. scoparium*-hosted specimens. Ascomycota are represented by 15 orders comprising 71 genera and species; Basidiomycota 9 orders and 195 genera and species; Deuteromycotina by 21 Hyphomycetes and 8 Coelomycetes. Details of their ranges throughout New Zealand are not complete.

*Leptospermum scoparium* ectomycorrhizae and endomycorrhizae (vesicular-arbuscular) are frequent yet the number of partners is unknown, and endomycorrhizae infection appears to be more common (Moyersoen & Fittler 1999). Although Hawksworth et al. (1995) identified the order Glomales (Ascomycota) as the most common endomycorrhizal symbiont, the herbarium collection does not include any specimen from this order, probably due to the difficulties associated with classification and laboratory growth. However, Baylis (1971) successfully infected *L. scoparium* with an endomycorrhiza in laboratory conditions, and in a study of five South Island sites dominated by *Nothofagus*, *Pinus radiata*, or podocarp/broad-leaved forest, 5 of the 12 endomycorrhizal symbionts described were found in association with *L. scoparium*, whereas only 10–36% of the infections were ectomycorrhiza at four of these sites (Cooper 1976). *L. scoparium* is one of the principal ectomycorrhizal hosts in New Zealand's endemic flora, with *Kunzea ericoides* and *Nothofagus* spp. (Hall et al. 1998). *L. scoparium* ectomycorrhizal infection appears to be determined by the presence of the appropriate inoculum and alternative host plant species, particularly *Nothofagus* spp. (Moyersoen & Fitter 1999). The ectomycorrhizal species recorded in New Zealand have recently been reviewed, listing 22 Basidiomycota and 6 Ascomycota families in association with *L. scoparium* (Orlovich & Cairney 2004). The invasive basidiomycete *Amanita muscaria*, often found with *L. scoparium* (Ridley 1991), is considered able to displace the native species (Orlovich & Cairney 2004).

The principal role of *L. scoparium* mycorrhizal partners is the improvement of phosphorus uptake (Baylis 1971; Johnson 1976; Hall 1977) allowing rapid growth and exploitation of available light (Wardle 1991). The level of mycorrhizal infection correlates with available phosphorus and growth conditions (Baylis 1975; Cooper 1975; Hall 1975). The development of *L. scoparium* ectomycorrhizae may also facilitate the growth and succession of *Nothofagus* spp. seedlings (Baylis 1980).

A narrow but characteristic range of *L. scoparium* endophytic fungi was reported from a study in the Auckland province (Johnston 1998). *Phyllosticta* spp., in association with *Diploceras leptospermi* and Coelomycete, dominated natural populations, with a range of other species present in insignificant and variable proportions. The opportunist endophytes *Botryosphaeria* and *Alternaria* sp. were prominent in planted *L. scoparium* stands, indicative of a host under environmental pressure (Johnston 1998). Within natural sites neither the species diversity nor the variability of infection rate could be explained by any obvious correlation with plant age or any environmental factor (Johnston 1998). *Phyllosticta* species were specific to *L. scoparium* and not recorded on *Kunzea ericoides*, yet *D. leptospermi* was present on both species (Johnston 1998) in contradiction to an earlier report (Bagnall & Sheridan 1972). The fungal species' pathogenicity is unknown though six of the families represented grow as epiphytes and are associated with leaf wounds (Johnston 1998). *Capnodium* spp. are also associated with *L. scoparium* foliage and bark, but as a result of *Eriococcus* spp. invasion (Hoy 1961).

## TRADITIONAL AND HISTORIC USES OF LEPTOSPERMUM SCOPARIUM

### Traditional uses

Six entries for *L. scoparium* are listed in the dictionary of Maori plant names, manuka and kahikatoa being the most common (Beever 1991). Manuka is most frequently used throughout New Zealand, and kahikatoa is common in Northland. The word kahikatoa also translates as a weapon made of *L. scoparium* (Williams 1975), and the plant name may be derived from this association. An alternative suggestion is that manuka was used as a generic name for the two common seral Myrtaceae species in New Zealand, the names kahikatoa and kanuka representing *L. scoparium* and *Kunzea ericoides*, respectively

(T. Roa pers. comm.). The common names of tea tree and red tea tree are explained by use of the leaves for a tea and the red colour of the wood. The Maori and common names for *K. ericoides* are manuka, kanuka, tea tree, and white tea tree, again indicating beverage use and wood colour, and often leading to understandable confusion and misidentification. Tī-tree is an incorrect name for both species, and refers to species of *Cordyline* (Brooker et al. 1987).

Maori used *L. scoparium* for food, medicine, and timber. Pia manuka, the sugary gum found occasionally on young branches, was considered a delicacy and given to infants, or was used to alleviate coughs in adults (Crowe 1981). Brooker et al. (1987) listed a number of traditional medicinal uses. A decoction of leaves was taken, applied as a salve, directly chewed, or the vapours inhaled. The bark was used in a similar way to alleviate bronchial complaints. The tough wood was harvested for implement making, and a review of museum artefacts illustrated seven tools made from the plant's timber (Cooper & Cambie 1991).

The first recorded European use was during James Cook's voyages, when *L. scoparium* leaves were initially used as a tea substitute, and later employed as an antiscorbutic in brewing beer (Cooper & Cambie 1991). Whalers continued to rely upon *L. scoparium* as a tea substitute (Brooker et al. 1987), giving rise to tea tree as a common name, and early settlers became so attached to the concoction that the importation of Chinese tea was considered unnecessary by one author (Crowe 1981). *L. scoparium* has continued to be valued for firewood and charcoal, and is often used for smoking fish.

### Ornamental use

*Leptospermum* is a genus of ornamental worthiness, and has been cultivated since its introduction to Europe. The greatest numbers of cultivars have been bred from *L. scoparium*. Approximately 150 named cultivars have been derived from *L. scoparium*, whilst the balance of the genus is represented by about 20–30 cultivars (Dawson 1997a).

Material collected during James Cook's first voyage of discovery included both *L. scoparium* and *K. ericoides*, both of which were incorrectly assigned to the genus *Philadelphus* in the unpublished *Primitiae Florae Novae Zelandiae*, prepared by Solander (Harris 2001). Three species were listed as growing at Kew Gardens by 1789, and prior to this four species of greenhouse *Philadelphus* were offered to the public in the late 1770s (Cooper & Cambie 1991). The specimens were subsequently reclassified cor-

rectly as either *L. scoparium* or *K. ericoides* (Harris 2001). *L. scoparium* was first described in 1776 from material collected from Dusky Sound, Fiordland, by J. R. & G. Forster during Cook's second voyage. By 1896 *L. scoparium* was acclimatised in Cornwall and described as a favourite conservatory plant (Cooper & Cambie 1991).

The discovery and use of rare wild variants has enhanced the range of *L. scoparium* cultivars available. Outstanding single white- or pink-flowered specimens have been identified in the wild, and a number of double white- or pink-flowered plants discovered and propagated throughout the 20th century. A red-flowered plant was found in the wild twice, leading to the release of another set of cultivars. Wild prostrate forms have also been used (Dawson 1997a).

These unusual wild plants have been developed by deliberate hybridisation, and Lammerts (1945) pioneered controlled breeding in California. Subsequent horticulturists have increased the range of *L. scoparium* cultivars, notably E. F. Jenkins and Sons (Victoria, Australia), J. Hobbs (Auckland, New Zealand), Duncan and Davies (New Plymouth, New Zealand), and G. Hutchins (Essex, England) (Dawson 1997b). This development allowed Dawson (1997b) to list 23 outstanding named *L. scoparium* cultivars. More recently, Harris (2000) recorded the development of four named inter-specific cultivars, all having *L. scoparium* as one parent and one of the Australian species *L. rupestre*, *L. spectabile*, or *L. polygalifolium* as the other, and a *L. rotundifolium* × *L. scoparium* hybrid has been bred (Bicknell 1995).

Studies have also been completed to improve the horticultural qualities of *L. scoparium*. Pot plants have been developed (Bicknell 1985), cut flower life (Bicknell 1995) and flowering cue (Zieslin & Gottesman 1986) investigated, frost hardiness considered (Greer et al. 1991; Decourtye & Harris 1992), and tolerance to soil acidity studied (Berninger 1992). Nonetheless, one of the greatest drawbacks of cultivated *L. scoparium* in New Zealand is manuka blight, and a cultivar resistant to the scale insect pest has not yet been developed.

*Leptospermum scoparium* has been extensively planted in the milder areas of the British Isles as a semi-hardy garden plant and is described as ubiquitous in Ireland gardens (Cooper & Cambie 1991). Despite the extent of garden planting in the British Isles naturalisation is only reported at Tresco Abby, Isles of Scilly, where groves of self-sown seedlings are found (Bean 1973). It is probable

that naturalisation has occurred in the milder areas of England and Ireland but has not been reported. The species has also naturalised in Hawai'i, where escapes from garden plantings have colonised disturbed wet forest areas and become a significant weed (Wagner et al. 1990).

### Essential oils

Essential oils distilled from the leaves of *L. scoparium* have received considerable commercial attention during the last decade. The New Zealand Phytochemical Register – Part III (Cambie 1976) lists earlier research that identified these oils.

An analysis of 16 commercial samples of *L. scoparium* essential oil revealed 100 components, of which 51 were identified and made up about 95% of the content. The oils fell into three major sections, triketones approximately 20%, sesquiterpene hydrocarbons 60–70%, and monoterpene hydrocarbons about 5% (Christoph et al. 1999), in contrast to about 75% monoterpene hydrocarbon  $\alpha$ -pinene present in *Kunzea ericoides* (Perry et al. 1997a).

A review of the essential oils of New Zealand suggested that *L. scoparium* oils would differ between and within natural populations (Douglas et al. 1994), and this was confirmed by the variation of the component essential oils of natural populations of *L. scoparium* grown in a common garden experiment (Perry et al. 1997b). Two plants from each population were sampled: the East Cape population contained a high triketone level, high levels of  $\alpha$ -pinene and  $\beta$ -pinene monoterpene hydrocarbons were found in Northland populations, and the balance of populations contained a complex mix of sesquiterpene and oxygenated sesquiterpene hydrocarbons. Australian *L. scoparium* samples grown in the same common environment had a higher monoterpene level than the New Zealand populations. The *L. scoparium* chemotypes reported matched the morphological types to some degree (Perry et al. 1997b).

Porter & Wilkins (1998) showed a similar pattern to those reported by Perry et al. (1997b), describing four groups of oil profiles found in wild populations: triketone-rich in the East Cape; monoterpene-, linalool-, and eudesmol-rich in Nelson; monoterpene- and pinene-rich in Canterbury; and triketone-, linalool-, and eudesmol-deficient in the rest of New Zealand. The average composition of *L. scoparium* essential oil was defined as  $\leq 3\%$  monoterpenes,  $\geq 60\%$  sesquiterpenes, and  $\leq 30\%$  oxygenated sesquiterpenes and triketones.

A detailed field study of New Zealand *L. scoparium* populations confirmed the presence of *L.*

*scoparium* chemotypes: monoterpene-enriched areas in Northland and the West Coast, triketone-enriched in East Cape and Marlborough, and sesquiterpene-rich oils throughout the rest of the country. Eleven chemotypes were recognised by the division of the major oil types referred to above and subdivision of the sesquiterpenes and oxysesquiterpenes (Douglas et al. 2004). The triketone-enriched oils have been found to carry the greatest antibacterial activity (Christoph et al. 2000), and are marketed as Manex™.

A chemotaxonomic analysis of *Leptospermum* has been completed. In dealing with species allied to *L. scoparium*, Brophy et al. (1999) showed that Australian *L. scoparium* populations in Victoria and Tasmania had different essential oil profiles from the New Zealand populations; in particular, triketones were not found. The persistent woody-fruited group of *Leptospermum* established by Thompson (1989) was not amended, and in general the *L. scoparium* essential oils did not differ in comparison with this group; however, the authors concluded that *L. scoparium* is a variable taxon that may require division (Brophy et al. 1999).

Nevertheless, within-population variation of essential oil content was shown in a study of *L. scoparium* grown in a common garden experiment from seed collected from five wild plants within a 5 m<sup>2</sup> area (Porter et al. 1998). The oil profiles of both young and mature plants differed within and between seasons, and the principal component responsible for most variation differed between plants whenever sampled. The morphology of the plants also differed markedly. The need for extensive sampling over a period of more than one growing season to produce reliable essential oil profile data for chemotaxonomic or variety selection was acknowledged.

### Manuka honey

Cockayne (1916) recognised *L. scoparium* as a major source of superfluous honey produced by the introduced honeybee, reflecting the abundance of the plant and the surplus nectar production. Butz Huryn (1995) reviewed the literature in detail. *L. scoparium* honey has a distinctive flavour, colour, and consistency and until recently was used solely for culinary purposes.

A number of studies analysing the antibacterial activities of New Zealand honeys have been completed. Whilst many honey types contained significant levels of antibacterial activity due to enzyme-produced hydrogen peroxide, only *L. scoparium* (manuka) honey often contained a relatively high

level of non-peroxide activity (Molan et al. 1988; Allen et al. 1991). The non-peroxide antibacterial activity was considered linked to the floral source (Molan & Russell 1988). However, *L. scoparium* honey samples have demonstrated a considerable range of potency of non-peroxide antibacterial activity. A typical agar diffusion assay study reporting a mean antibacterial activity of 18.6 units, equivalent to the activity of 18.6% w/v phenol, for 19 *L. scoparium* honey samples, with a standard deviation of 8 units (Allen et al. 1991). The variability was initially attributed to sample misidentification or processing differences (Allen et al. 1991), and later to a regional difference in phytochemical composition or concentration (Molan 1995). The non-peroxide antibacterial activity of *L. scoparium* honey was named the Unique Manuka Factor (UMF®), leading to the development of a range of medical products from *L. scoparium* honey containing high levels of UMF®.

Attempts to identify the active component responsible for the non-peroxide antibacterial activity present in *L. scoparium* honey have continued unsuccessfully. Two approaches have been investigated: seeking correlation between the antibacterial activity and the trace organic substances to determine the honey's floral source identified by GC-MS, and the identification of the fraction responsible for the non-peroxide activity. Identification of the components of *L. scoparium* honey confirmed that the constituents are different from those found in the antibacterial *L. scoparium* essential oil (Tan et al. 1988); the triketones found responsible for the antibacterial activity of the essential oil (Christoph et al. 2000) are not found in the honey. The identified phytochemical components of *L. scoparium* honey are similar regionally throughout New Zealand, accordingly not accounting for the non-peroxide variability (Tan et al. 1989; Wilkins et al. 1993; Weston et al. 2000). However, the phytochemical components of New Zealand *L. scoparium* honey differ from those of the Australian *L. polygalifolium* honey that also exhibits a non-peroxide antibacterial effect (Yao et al. 2003).

Extraction of potentially active organic fractions (Russell et al. 1990) was followed by the isolation of the phenolic components (Weston et al. 1999), oligosaccharides (Weston & Brocklebank 1999), and antibacterial bee peptides (Weston et al. 2000). These components were found to account for little of the non-peroxide activity, and Weston (2000) suggested that the non-peroxide antibacterial effect was an additional peroxide effect and that the assay

developed to remove peroxide from honey (Molan & Russell 1988) was consistently failing.

However, the residual hydrogen peroxide in *L. scoparium* honey has been shown not to account for the non-peroxide antibacterial activity by chemical manipulation (Snow & Manley-Harris 2004). Furthermore, a difference in the mode of action of dissimilar honeys has been indicated in studies that determine the minimum inhibitory concentrations for control of wound-infecting bacterial species (Willix et al. 1992). Methicillin-resistant *Staphylococcus aureus* responded to the same concentrations of *L. scoparium* honey and a honey with activity due to hydrogen peroxide, yet vancomycin-resistant *Enterococcus faecium* required approximately double the concentration of the latter honey to be inhibited compared with the *L. scoparium* honey (Cooper et al. 2002). Additionally, the peroxide antibacterial activity of honey is not effective against all bacterial species. *Helicobacter pylori* was inhibited by a 5% solution of *L. scoparium* honey but was not inhibited by a 40% solution of a honey with activity due to hydrogen peroxide, whereas both honeys were equally effective against *Staphylococcus aureus* (Al Somal et al. 1994). These observations indicate that an as yet unknown agent other than hydrogen peroxide significantly contributes to the antibacterial activity of *L. scoparium* honey.

## CONCLUSIONS

*Leptospermum scoparium* is tolerant of infertile environments, thriving in a wide range of marginal and disturbed environments. The seral habitat in New Zealand has been greatly extended by human vegetation disturbance, and due to its invasive nature, the species has been regarded as an agricultural woody weed. Recent studies have altered the perception of *L. scoparium*. The species' role in erosion control, carbon sequestration, and vegetation restoration by succession, along with the commercial value of the essential oils, honey, and ornamental varieties, make further examination of the species necessary and timely.

The taxonomic status of the species needs to be thoroughly clarified in New Zealand and Australia. In all probability *L. scoparium* is an undefined species aggregate in New Zealand (P. de Lange pers. comm.) The relationship of *L. scoparium* populations within New Zealand, populations within Australia, between New Zealand and Australian populations, and the closely related Australian species, should

be investigated. The Australian tea tree *Melaleuca alternifolia* (Myrtaceae), which is used for essential oil production, has received just such a comprehensive treatment (Rossetto et al. 1999; Lee et al. 2002). Conventional techniques such as uniform environment studies and essential oil profiles, with modern molecular genetic studies, should be included in such a study.

The increased seral range of *L. scoparium* has most likely allowed gene flow between previously isolated populations in New Zealand. The genetic properties of unique populations, for example, the dwarf population identified on the Kaikoura coast (Harris 1994), may be lost due to interbreeding. The need to sustain genetic integrity of New Zealand species has been recognised (Simpson 1992; Atkinson 1994), and *L. scoparium* is certainly another example of a species exhibiting a combination of phenotypic and genotypic variation throughout its natural range.

A revised systematic treatment of *L. scoparium* would resolve many questions surrounding the species. The regional differences of essential oils profiles and honey non-peroxide antibacterial activity may relate to genetic differences between populations, but this awaits experimental confirmation. Horticultural cultivar development may be enhanced, particularly the search for a plant resistant to manuka blight. Agronomic development of the species as a crop plant providing an abundant and reliable source of the pharmacologically active essential oils and honey could be pursued. The conservation and, where necessary, the repopulation of genetically unique varieties could be actively promoted to ensure the survival of the entire genetic spectrum of this interesting and valuable species.

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## LEADERS' PLEDGE FOR NATURE

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### *United to Reverse Biodiversity Loss by 2030 for Sustainable Development*

We, political leaders participating in the United Nations Summit on Biodiversity, representing 64\* countries from all regions and the European Union, have come together today, on 28 September 2020, ahead of the Summit to send a united signal to step up global ambition for biodiversity and to commit to matching our collective ambition for nature, climate and people with the scale of the crisis at hand.

We reaffirm our commitment to international cooperation and multilateralism, based on unity, solidarity and trust among countries, peoples and generations, as the only way for the world to effectively respond to current and future global environmental crises.

We are in a state of planetary emergency: the interdependent crises of biodiversity loss and ecosystem degradation and climate change - driven in large part by unsustainable production and consumption - require urgent and immediate global action. Science clearly shows that biodiversity loss, land and ocean degradation, pollution, resource depletion and climate change are accelerating at an unprecedented rate. This acceleration is causing irreversible harm to our life support systems and aggravating poverty and inequalities as well as hunger and malnutrition. Unless halted and reversed with immediate effect, it will cause significant damage to global economic, social and political resilience and stability and will render achieving the Sustainable Development Goals impossible.

Biodiversity loss is both accelerated by climate change and at the same time exacerbates it, by debilitating nature's ability to sequester or store carbon and to adapt to climate change impacts. Ecosystem degradation, human encroachment in ecosystems, loss of natural habitats and biodiversity and the illegal wildlife trade can also increase the risk of emergence and spread of infectious diseases. COVID-19 shows that these diseases have dramatic impacts not only on loss of life and health but across all spheres of society.

Nature fundamentally underpins human health, wellbeing and prosperity. We need to appropriately value nature and the services it provides as we make decisions and recognize that the business case for biodiversity is compelling. The benefits of restoring natural resources outweigh the costs ten-fold, and the cost of inaction is even higher.

Despite ambitious global agreements and targets for the protection, sustainable use and restoration of biodiversity, and notwithstanding many local success stories, the global trends continue rapidly in the wrong direction. A transformative change is needed: we cannot simply carry on as before.

This Pledge is a recognition of this crisis and an expression of the need for a profound re-commitment from World leaders to take urgent action. Against the backdrop of COVID19, which has crippled the world's economies and pressured governments everywhere to begin the process of rebuilding and renewing, decisions made now will have ramifications for all of us and for generations to come.

We are committed to taking the necessary actions to achieve the vision of Living in Harmony with Nature by 2050. To put the world on the right track towards this long-term goal will require strong political will combined with real accountability and the appropriate legal, economic and financial tools and incentives. Everyone, governments, business and individuals, has a role to play. We must broaden and strengthen the movement for change.

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\*\* As of 26/9/2020 –

The latest information on the number of endorsements can be found at <https://www.leaderspledgefornature.org/>

We therefore commit to undertake the following urgent actions over the next ten years as part of the UN Decade of Action to achieve Sustainable Development and to put nature and biodiversity on a path to recovery by 2030:

1. We will ensure that our response to the current health and economic crisis is green and just and contributes directly to recovering better and achieving sustainable societies; we commit to putting biodiversity, climate and the environment as a whole at the heart both of our COVID-19 recovery strategies and investments and of our pursuit of national and international development and cooperation.
2. We commit to the development and full implementation of an ambitious and transformational post-2020 global biodiversity framework for adoption at the 15<sup>th</sup> Conference of Parties of the UN Convention on Biological Diversity (CBD CoP 15) as a key instrument to reach the Sustainable Development Goals that includes:
  - a. A set of clear and robust goals and targets, underpinned by the best available science, technology, research as well as indigenous and traditional knowledge;
  - b. Commitments to address the direct and indirect drivers of biodiversity loss and halt human induced extinction of species, to ensure species populations recover, and to significantly increase the protection of the planet's land and oceans through representative, well-connected and effectively managed systems of Protected Areas and Other Effective Area-Based Conservation Measures, and to restore a significant share of degraded ecosystems;
  - c. Commitment to the full and effective participation of indigenous peoples and local communities in decision making and recognition of their rights, as acknowledged in relevant national and international instruments;
  - d. Commitments backed up by a strong monitoring and review mechanism, and means of implementation commensurate with the challenge of halting and reversing the decline in biodiversity;
  - e. Commitments to strengthen the cooperation among relevant multilateral environmental agreements, international organizations and programmes to contribute to effective and efficient implementation of the biodiversity framework.
3. We will re-double our efforts to end traditional silo thinking and to address the interrelated and interdependent challenges of biodiversity loss, land, freshwater and ocean degradation, deforestation, desertification, pollution and climate change in an integrated and coherent way, ensuring accountability and robust and effective review mechanisms, and lead by example through actions in our own countries.
4. We commit to transition to sustainable patterns of production and consumption and sustainable food systems that meet people's needs while remaining within planetary boundaries, including by:
  - a. Accelerating the transition to sustainable growth, decoupled from resource use, including through moving towards a resource-efficient, circular economy, promoting behavioral changes and a significant scale-up in nature-based solutions and ecosystem-based approaches on land and at sea;

- b. Supporting sustainable supply chains, significantly reducing the impact on ecosystems caused by global demand for commodities and encouraging practices that regenerate ecosystems;
  - c. Shifting land use and agricultural policies away from environmentally harmful practices for land and marine ecosystems and promoting sustainable land and forest management to significantly reduce habitat loss, unsustainable land use change, deforestation and fragmentation, achieve land degradation neutrality and maintain genetic diversity;
  - d. Eliminating unsustainable uses of the ocean and its resources, including illegal, unreported and unregulated fishing as well as unsustainable fishing and aquaculture practices, and working collaboratively to develop a coherent global approach to protect the ocean and sustainably use its resources, including by aiming to conclude at the next intergovernmental conference, the negotiations for an effective international legally binding instrument under the United Nations Convention on the Law of the Sea on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction;
  - e. Significantly enhancing our efforts to reduce the negative impacts of invasive alien species;
  - f. Significantly reducing pollution in the air, on land, in soil, freshwater and the ocean, in particular by eliminating plastic leakage to the ocean by 2050 as well as pollution due to chemicals, excess nutrients and hazardous waste, including through the strengthening of global coordination, cooperation and governance on marine litter and microplastics, with focus on a whole life-cycle approach and supporting an ambitious outcome for the process on the *Strategic approach and sound management of chemicals and waste beyond 2020*;
5. We commit to raising ambition and aligning our domestic climate policies with the Paris Agreement, with enhanced Nationally Determined Contributions and long-term strategies consistent with the temperature goals of the Paris Agreement, and the objective of Net Zero greenhouse gas emissions by mid-century, strengthening climate resilience in our economies and ecosystems and promoting convergence between climate and biodiversity finance.
6. We commit to ending environmental crimes which can seriously impact efforts to tackle environmental degradation, biodiversity loss, and climate change, and can undermine security, the rule of law, human rights, public health, and social and economic development. We will ensure effective, proportionate and dissuasive legal frameworks, strengthen national and international law enforcement and foster effective cooperation. This also includes tackling environmental crimes involving organized criminal groups, such as the illicit trafficking of wildlife and timber, as serious crimes, acting along the whole supply chain, reducing the demand for illegal wildlife, timber and by-products, and engaging with local communities to ensure sustainable solutions for people, nature and the economy.
7. We commit to mainstreaming biodiversity into relevant sectoral and cross-sectoral policies at all levels, including in key sectors such as food production, agriculture, fisheries and forestry, energy, tourism, infrastructure and extractive industries, trade and supply chains, and into those key international agreements and processes which hold levers for change, including the G7, G20, WTO, WHO, FAO, and UNFCCC and UNCCD. We will do this by ensuring that across the whole of government, policies, decisions and investments account for the value of nature and biodiversity, promote biodiversity conservation, restoration, sustainable use and the access to genetic resources and the fair and equitable sharing of benefits arising from their utilization.

8. We commit to integrating a “One-Health” approach in all relevant policies and decision-making processes at all levels that addresses health and environmental sustainability in an integrated fashion.
9. We will strengthen all financial and non-financial means of implementation, to transform and reform our economic and financial sectors and to achieve the wellbeing of people and safeguard the planet by, inter alia:
  - a. Incentivizing the financial system, nationally and internationally, including banks, funds, corporations, investors and financial mechanisms, to align financial flows to environmental commitments and the Sustainable Development Goals, to take into account the value of nature and biodiversity, promote biodiversity conservation, restoration and its sustainable use in their investment and financing decisions, and in their risk management, as well as including through encouraging the use of taxonomies;
  - b. Enhancing the mobilization of resources from all sources, public and private, maximizing the effectiveness and efficiency of the use of existing resources and facilitating access to support where needed, in order to significantly scale up support for biodiversity, including through nature-based solutions, which contribute effectively not only to the achievement of biodiversity and climate goals, but to sustainable development, livelihoods and poverty alleviation where needed;
  - c. Eliminating or repurposing subsidies and other incentives that are harmful to nature, biodiversity and climate while increasing significantly the incentives with positive or neutral impact for biodiversity across all productive sectors;
  - d. Improving the efficiency, transparency and accountability in the use of existing resources, including through co-benefits, finance tracking and reporting frameworks.
10. We commit that our approach to the design and implementation of policy will be science-based, will recognize the crucial role of traditional and indigenous knowledge as well as science and research in the fight against ecosystem degradation, biodiversity loss and climate change; and will engage the whole of society, including business and financial sectors, indigenous peoples and local communities, environmental human rights defenders, local governments and authorities, faith-based groups, women, youth, civil society groups, academia, and other stakeholders.

In endorsing this Pledge for Nature, we commit ourselves not simply to words, but to meaningful action and mutual accountability to address the planetary emergency. It marks a turning point, and comes with an explicit recognition that we will be judged now and by future generations on our willingness and ability to meet its aims. With this Pledge, we also aim to support the United Nations system and its fundamental role in catalysing the global response to this crisis in the upcoming decisive months and years.

We will join forces in the run up to the key international events and processes taking place throughout 2021, including the G7, the G20, the IUCN World Conservation Congress, the fifth UN Environment Assembly, UNFCCC COP26 and the UN Ocean Conference, aiming to achieve ambitious and realistic outcomes to pave the way for a strong Post-2020 Global Biodiversity Framework, and we urge all stakeholders to join us in making commitments to address the planetary emergency on the road to CBD CoP 15 and beyond.

We commit to meeting again next year, and beyond, at such key international events, in particular at the next UN General Assembly High Level Week in September 2021, to review our progress and reaffirm these commitments.

COP 26 pledge signees

02.11.2021

## GLASGOW LEADERS' DECLARATION ON FORESTS AND LAND USE

We, the leaders of the countries identified below:

Emphasise the critical and interdependent roles of forests of all types, biodiversity and sustainable land use in enabling the world to meet its sustainable development goals; to help achieve a balance between anthropogenic greenhouse gas emissions and removal by sinks; to adapt to climate change; and to maintain other ecosystem services.

Reaffirm our respective commitments, collective and individual, to the UN Framework Convention on Climate Change and the Paris Agreement, the Convention on Biological Diversity, the UN Convention to Combat Desertification, the Sustainable Development Goals; and other relevant initiatives.

Reaffirm our respective commitments to sustainable land use, and to the conservation, protection, sustainable management and restoration of forests, and other terrestrial ecosystems.

Recognise that to meet our land use, climate, biodiversity and sustainable development goals, both globally and nationally, will require transformative further action in the interconnected areas of sustainable production and consumption; infrastructure development; trade; finance and investment; and support for smallholders, Indigenous Peoples, and local communities, who depend on forests for their livelihoods and have a key role in their stewardship.

Highlight the areas of strong progress in recent years and the

opportunities before us to accelerate action.

We therefore commit to working collectively to halt and reverse forest loss and land degradation by 2030 while delivering sustainable development and promoting an inclusive rural transformation.

We will strengthen our shared efforts to:

Conserve forests and other terrestrial ecosystems and accelerate their restoration;

Facilitate trade and development policies, internationally and domestically, that promote sustainable development, and sustainable commodity production and consumption, that work to countries' mutual benefit, and that do not drive deforestation and land degradation;

Reduce vulnerability, build resilience and enhance rural livelihoods, including through empowering communities, the development of profitable, sustainable agriculture, and recognition of the multiple values of forests, while recognising the rights of Indigenous Peoples, as well as local communities, in accordance with relevant national legislation and international instruments, as appropriate;

Implement and, if necessary, redesign agricultural policies and programmes to incentivise sustainable agriculture, promote food security, and benefit the environment;

Reaffirm international financial commitments and significantly increase finance and investment from a wide variety of public and private sources, while also improving its effectiveness and accessibility, to enable sustainable agriculture, sustainable forest management, forest conservation and restoration, and support for Indigenous Peoples and local communities;

Facilitate the alignment of financial flows with international

goals to reverse forest loss and degradation, while ensuring robust policies and systems are in place to accelerate the transition to an economy that is resilient and advances forest, sustainable land use, biodiversity and climate goals.

We urge all leaders to join forces in a sustainable land use transition. This is essential to meeting the Paris Agreement goals, including reducing vulnerability to the impacts of climate change and holding the increase in the global average temperature to well below 2°C and pursuing efforts to limit it to 1.5°C, noting that the science shows further acceleration of efforts is needed if we are to collectively keep 1.5°C within reach. Together we can succeed in fighting climate change, delivering resilient and inclusive growth, and halting and reversing forest loss and land degradation.

NEW ENDORSEMENTS SINCE 10/11/21: The Holy See, Nicaragua, Singapore, Turkmenistan

% OF FOREST COVERED BY ENDORSERS: 90.94%

HECTARES OF FOREST COVERED BY ENDORSERS:  
3,691,510,640

SQUARE MILES OF FOREST COVERED BY  
ENDORSERS: 14,252,996

Total: 141

1. Albania
2. Andorra
3. Angola
4. Argentina
5. Armenia
6. Australia

7. Austria
8. Azerbaijan
9. Bangladesh
10. Belgium
11. Belize
12. Bhutan
13. Bosnia and Herzegovina
14. Botswana
15. Brazil
16. Brunei Darussalam
17. Bulgaria
18. Burkina Faso
19. Cameroon
20. Canada
21. Central African Republic
22. Chad
23. Chile
24. China
25. Colombia
26. Costa Rica
27. Côte d'Ivoire
28. Croatia
29. Cuba
30. Cyprus
31. Czechia
32. Denmark
33. Dominican Republic
34. Democratic Republic of the Congo
35. Ecuador
36. El Salvador
37. Equatorial Guinea
38. Estonia
39. Eswatini
40. European Commission on behalf of the European Union

41. Fiji
42. Finland
43. France
44. Gabon
45. Georgia
46. Germany
47. Ghana
48. Greece
49. Grenada
50. Guatemala
51. Guinea Bissau
52. Guyana
53. Haiti
54. Holy See
55. Honduras
56. Hungary
57. Iceland
58. Indonesia
59. Ireland
60. Israel
61. Italy
62. Jamaica
63. Japan
64. Kazakhstan
65. Kenya
66. Kyrgyzstan
67. Latvia
68. Lebanon
69. Liberia
70. Liechtenstein
71. Lithuania
72. Luxembourg
73. Madagascar
74. Malawi

75. Malaysia
76. Mali
77. Malta
78. Mauritius
79. Mexico
80. Moldova
81. Monaco
82. Mongolia
83. Montenegro
84. Morocco
85. Mozambique
86. Nepal
87. Netherlands
88. New Zealand
89. Nicaragua
90. Niger
91. Nigeria
92. North Macedonia
93. Norway
94. Pakistan
95. Panama
96. Papua New Guinea
97. Paraguay
98. Peru
99. Philippines
100. Poland
101. Portugal
102. Republic of the Congo
103. Romania
104. Russia
105. Rwanda
106. Saint Lucia
107. Saint Vincent and the Grenadines
108. Samoa

109. San Marino
110. Sao Tome and Principe
111. Senegal
112. Serbia
113. Seychelles
114. Sierra Leone
115. Singapore
116. Slovakia
117. Slovenia
118. Somalia
119. South Korea
120. Spain
121. Sri Lanka
122. Suriname
123. Sweden
124. Switzerland
125. Syria
126. Tanzania
127. Togo
128. Tonga
129. Turkey
130. Turkmenistan
131. Uganda
132. Ukraine
133. United Arab Emirates
134. United Kingdom
135. United States of America
136. Uruguay
137. Uzbekistan
138. Vanuatu
139. Vietnam
140. Zambia
141. Zimbabwe

12th November 2021 (6pm)