Restoring an arboretum of Lauraceae at Lake Eacham, Crater Lakes National Park, Queensland

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Abstract

An arboretum is a living collection of trees that serve multiple roles in public education and recreation, scientific research, and a means of practising ex-situ conservation of botanical resources. In the mid to late 1980s, local botanists and rangers planted 84 species of native Australian rainforest laurels (Lauraceae) in the Lake Eacham section of Crater Lakes National Park, Queensland, hence establishing the Lake Eacham Laurel Arboretum. In addition, a smaller living collection of native trees from the fig (Moraceae), macadamia (Proteaceae) and myrtle (Myrtaceae) families from the Wet Tropics Bioregion were also planted. The laurels, our focal group in this work, are a biologically, culturally, and economically important group of rainforest trees. As laurels are rather nondescript in appearance and have inconspicuous flowers, public awareness of native laurels is dismal. The collection could serve as a venue for public education and as a scientific resource for this group of trees. Unfortunately, the site has fallen into obscurity over the last decade, and rainforest regrowth has suppressed many of the original plantings. We therefore began the groundwork for rejuvenating the Lake Eacham Laurel Arboretum by resurveying the original plantings of laurels. To this end, we established a grid system over the site and re-identified, tagged, measured, and mapped all surviving Lauraceae. We identified 59 laurel species encompassing seven genera and 164 individual stems, representing a 27.9% reduction from the 84 species planted. Even in their diminished state, these plantings exceed collections in other regional botanical gardens, representing collections from Cape York, the Wet Tropics and the southeast Queensland – northern New South Wales region. The arboretum is of considerable scientific value, and we hope that this study will facilitate management and development of this largely forgotten site and help elevate the site to a significant public recreational and educational space for locals and visitors to the Atherton Tablelands.

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Introduction

Botanical gardens and arboreta are recreational spaces containing living collections of plants, the latter with an emphasis on trees, and are important public spaces for recreation and education. Such public attractions may offer a sustainable form of tourism development, with positive impacts on the tourism economy in their local region (Sharpley 2007). Studies also show that such public spaces can positively influence environmental attitudes (Williams *et al.* 2015). Additionally, botanical gardens and arboreta can serve as focal sites for scientific research (Dosmann 2007), botanical and long-term ecological monitoring, plant physiological studies (Einset 1984) conservation of cultural and natural resources, and also as living seed sources for restoration projects (Raven 1981).

Today, as climate change puts increasing pressure on ecosystems around the world, environmental degradation has become one of the most pressing issues of our century (Scholze *et al.* 2006). Anthropogenic influences such as deforestation, urbanisation, and CO_2 emissions also threaten plant biodiversity, with a third of the world's vascular plants facing potential extinction (Chen *et al*. 2018; Weisse *et al*. 2023). Plant conservation through the development of arboreta and botanical gardens is therefore more necessary than ever for the preservation of forest environments and plant biodiversity, and for public education.

An important way that botanical gardens and arboreta can be used to facilitate learning and research is through establishing living collections of specific groups of plants (Raven 1981). In South Australia, for instance, the privately-run Currency Creek Arboretum features the largest diversity of eucalypts in the world (~900 species) (Nicolle 2023), and serves as an important research resource for eucalypt specialists. Another thematic arboretum, the Palmetum in Townsville, Queensland, features an impressive collection of about 300 species of palms. Such living collections of trees are highly complementary to those curated in botanical gardens, which typically focus more on exhibiting a wider variety of plants, as well as exotic and ornamental plant life forms.

Given that tropical regions are strongholds of the world's botanical diversity, botanical gardens and arboreta should aim to curate a good representation of the larger families of tropical plants. North-east Queensland is one of the most botanically diverse regions in Australia, particularly with respect to trees and shrubs. In the Far North Queensland region alone, there are an estimated 1,700 species of native trees and shrubs (Zich & Crayn 2020), and more are described annually. Despite this, few living collections in the region serve as educational and research outposts of this diverse tree flora. In north-east Queensland, publicly accessible living collections with representation of the regional flora are notably situated in lowland areas and include the Cairns Botanic Gardens, Cooktown Botanic Gardens, the newly established Mossman Botanic Gardens, and three gardens (Queen's Garden, Anderson's Garden and the Palmetum) in the Townsville area. These public gardens showcase a wide variety of exotic and native plants but have very small collections of thematic plantings of specific tree families (with the exception of the Palmetum). With most of the public gardens being situated in the lowlands, there is a niche for public gardens in the climatically different uplands region for both public education and the conservation of genetic resources.

The Atherton Tablelands is a biologically diverse upland area in north Queensland's Wet Tropics with a subtropical climate ideal for establishing living plant collections less suited to warmer lowland regions. Indeed, situated within the previous Commonwealth Scientific and Industrial Research Organisation (CSIRO) Tropical Forest Research Centre premises in Atherton is a 3.6 ha arboretum with a significant collection of over 500 native trees, with significant representation of trees from the Wet Tropics and Cape York region

(CSIRO 2020). However, with closure of the Atherton CSIRO office and the sale of the premises, the fate of the living tree collection in the arboretum is highly uncertain. A few other substantial private living collections (e.g. the residence of botanists Gary and Nada Sankowsky at Walkamin, Queensland) also exist, but access to these collections is by private arrangement. One final example of a living botanical collection, and the focus of this article, is a small but obscure planting near Lake Eacham, Crater Lakes National Park. In this little-known living collection, records from the Queensland Parks and Wildlife Service, a branch of the Department of Environment and Science, indicate that 85 native species of the Laurel family (Lauraceae) were planted between 1984 and 1988, and this planting was referred to, rather matter-of-factly, as the Lake Eacham Lauraceae Arboretum (Fig. 1). Concurrent with the Lauraceae, various native species of the fig (Moraceae), macadamia (Proteaceae) and myrtle (Myrtaceae) families were also planted close by (Fig. 1).

Lamentably, the site has been little managed over the past two decades, and native rainforest regrowth has suppressed many of the original plantings. The aims of this article are twofold: to (1) provide a history of the Lake Eacham Lauraceae Arboretum, and (2) to establish the groundwork for further developing it as a public education resource and recreational site. To accomplish our second objective, we conducted a study to assess the condition of the original plantings and to map the living collection, with the hope that these data will contribute towards the ongoing management and development of the Lake Eacham Lauraceae Arboretum.

Laurels and the history of the Lake Eacham Lauraceae Arboretum

The Lauraceae consist of *c.* 50 genera and around 2500–3000 species worldwide and are a significant contributor to the forest floras of both the Old and New World Tropics and subtropics (van der Werff & Richter 1996). With the exception of the leafless parasitic vines, dodder (*Cassytha* spp.), members of the Lauraceae are predominantly evergreen trees or shrubs and possess alternate, opposite or whorled leaves that are of a leathery texture, often with essential oil dots that give many species an

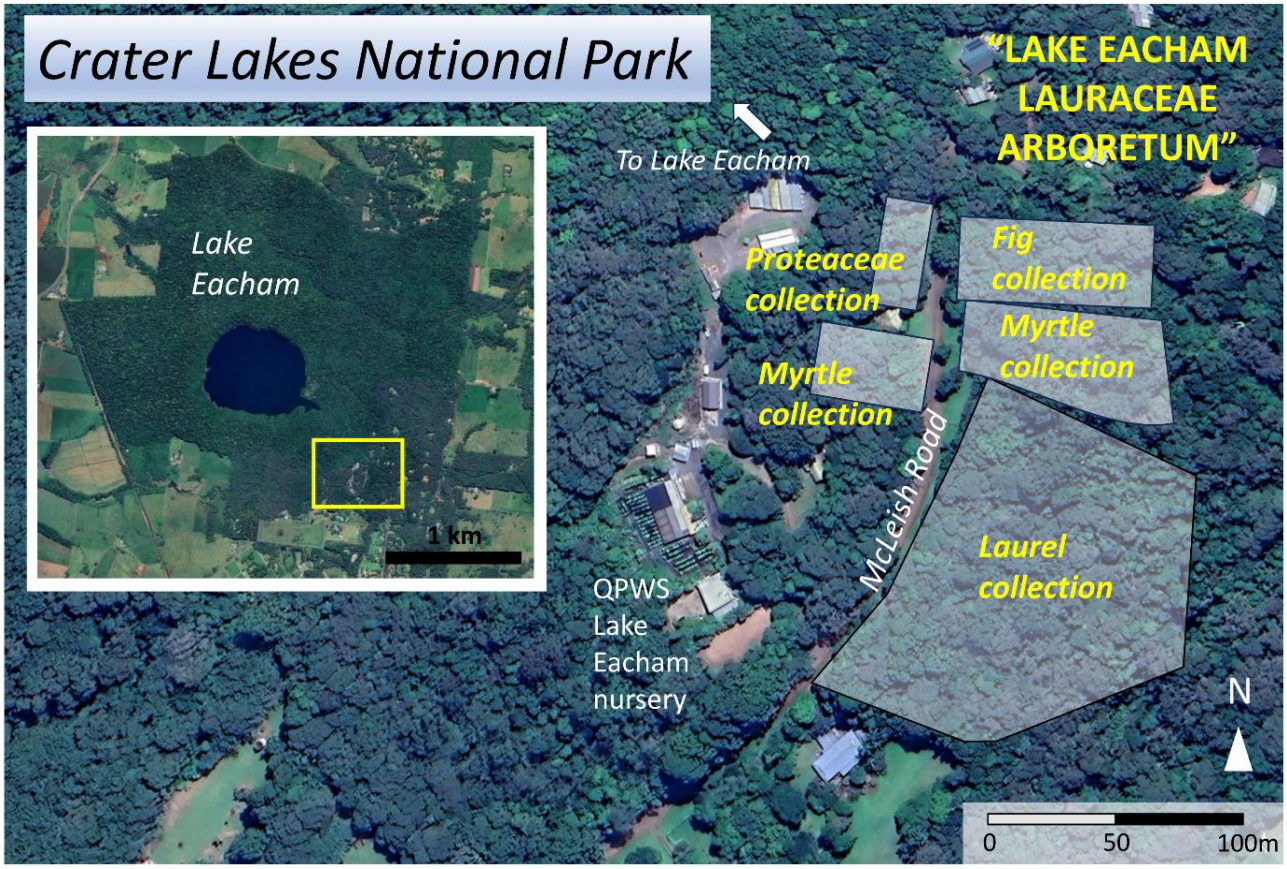

Figure 1. Aerial map showing the location of the Lake Eacham Lauraceae Arboretum.
The inset is an aerial view of the Lake Eacham section of the Crater Lakes National Park.

aromatic nature (Kostermans 1957). Flowers tend to be small and white, yellow, or green and borne on paniculate, racemose or capitellate inflorescences (Kostermans 1957), whilst fruits are typically fleshy and single-seeded (Cooper & Cooper 2004; Le Cussan & Hyland 2007). Perhaps the most well-known members of the Lauraceae are those with economic value, including the Avocado (*Persea americana*), spice-producing Cinnamon (*Cinnamomum zeylanicum*), Sassafras (*Sassafras albidum*) and Bay Leaf (*Laurus nobilis*). Various other species have also been documented for their medicinal uses, both traditional and clinical: *Cinnamomum cassia*, *Lindera aggregata*, and *Litsea cubeba* have been used for relieving stomach pain, treating kidney disease, or as antibacterial oils (Feng *et al.* 2022). In north Queensland, many Lauraceae were historically milled as cabinet woods, and the family displays high ecological value, being a key diet item of frugivorous birds and important in ecological restoration projects where many are considered framework species (Goosem & Tucker 2013, Tucker *et al.* 2023).

In Australia, the Lauraceae comprise one of the larger families of rainforest plants, with over 130 species distributed among eight genera: *Beilschmiedia*; *Cassytha*; *Cinnamomum*; *Cryptocarya*; *Endiandra*; *Lindera*; *Litsea*, and *Neolitsea* (Le Cussan & Hyland 2007). North Queensland (encompassing areas within the Wet Tropics and Cape York Bioregions) is the centre of diversity for Australian Lauraceae, with 96 native taxa (species, and including subspecies and varieties), and with representations of all eight Lauraceae genera native to the continent. The Southeast Queensland and northern New South Wales region is another centre of diversity for the Lauraceae, in particular for *Cryptocarya* (Whiffin & Hyland 1986). At least three naturalized species, Bay Leaf (*Laurus nobilis*), Avocado (*Persea americana*) and Camphor Laurel (*Cinnamomum camphora*) are also documented in Australia (Hyland 1989).

The first major work dealing specifically with Australian Lauraceae was by George Bentham (1870) who, with assistance from Ferdinand von Mueller, recognized 25 tree laurel species. Over the following century, Australian laurels continued to be described sporadically, most notably by C.T. White (White & Kajewski 1933). In 1989, CSIRO taxonomist Bernard Patrick Matthew Hyland ('Bernie Hyland') published an important taxonomic revision and monograph on the Australian Lauraceae, which recognized 115 species, of which 47 were new to science (Hyland 1989). Hyland's monumental work was an Australia-wide revision that untangled/categorised/sorted out the 120-years' accumulation of synonyms for many laurel species. After 30 years, Hyland's revision remains an authoritative resource. Few new laurel species have been described since, notably including *Cryptocarya whiffiana* (Le Cussan & Hyland 2007)*, C. cercophylla* (Cooper 2013) and *Endiandra inopinata* (Gray 2020) from Queensland's Wet Tropics, and *Endiandra wongawallenensis* from southeast Queensland (Weber & Forster 2021).

In order for field workers to identify laurels (and other rainforest trees) in the Australian tropics, Hyland created the first Tropical Rainforest Key (RFK) in 1971, which in its current iteration (RFK8) uses a LUCID key system useful for identifying plants even where only leaves are available (Zich & Crayn 2020). The RFK system also features single leaf scans for most laurel species based on the work of Chistophel & Hyland (1993). Also, Cooper and Cooper's (2004) beautifully illustrated *Fruits of the Australian Tropical Rainforest* is an invaluable resource for identifying rainforest laurels by their fruits. The Australian Tropical Herbarium public reference collection of dried plant specimens from the North Queensland region is also an important identification resource for both the public and professional users.

Despite the usefulness of these tools, ecologists and botanists who work in the tropics and subtropics will be quick to acknowledge the difficulties of identifying laurels in the field; the nondescript nature of laurels exacerbates difficulties in identifying dried sterile specimens. In our experience (DYPT and GH), there is little substitute to learning how to identify sterile specimens of laurels in the field by learning about species-specific characters from experienced botanists who have decades of field experience, and in having living specimens to observe or verify collections against. The establishment of a living collection of Lauraceae would therefore be of great value for plant enthusiasts and botanists.

Fortuitously, during Hyland's revision, he collected and germinated seeds from type specimens across Australia in order to describe seedlings at germination and saplings at 10th leaf stage (Hyland 1989). As Hyland's work came to a close, the

germinated seedlings were to be discarded, but in 1983 Hyland's colleague and fellow CSIRO botanist Geoff Tracey and Queensland Parks and Wildlife Service (QPWS) Lake Eacham Nursery Manager Nigel Tucker saw an opportunity to preserve an important scientific resource by planting selected saplings, creating a living collection of Australia's woody laurels. Seedlings of each species were potted at the QPWS Lake Eacham Nursery, and generally a minimum of three individuals of each species was selected for planting when seedlings attained 300–400 mm in height. Between 1984 and 1988, Tracey and Tucker planted Hyland's laurel seedlings in what was then a relatively bare area, with some Sarsaparilla (*Alphitonia petriei*) regrowth to 6 m in height, south-east of Lake Eacham (17°17′31"S, 145°37′53" E, 803 m a.s.l.) on McLeish Road opposite the QPWS Lake Eacham Nursery (Fig. 1). In total, Tracey and Tucker planted 301 individuals consisting of 84 species of laurels (Fig. S1). Plantings were in species clusters and marked with wooden markers with unique code numbers. A hand-drawn map was produced at the conclusion of planting (Fig. S1). Some signage indicating the species binomials was later erected for each species cluster. Additionally, a small collection of Moraceae, Myrtaceae and rainforest Proteaceae (the latter from seedlings donated by local naturalist Alan Gillanders) was also established in the vicinity of the Lauraceae plantings. (Contemporaneously, Tracey and Tucker also established a collection of Araucariaceae at Hallorans Hill Conservation Park in Atherton.) Following planting, stems were mulched using peanut shell, and weeds were excluded until trees were self-maintaining. Species confined to drier habitats, including *Cryptocarya williwilliana*, proved very difficult to maintain and frequently died back during winter months.

In 1997, Tucker's colleague David Fell, a QPWS Cairns-based botanist, conducted a census and found 209 plants consisting of 73 laurel species remained. In a memorandum he noted that "*Basic maintenance of the collection was also carried out. This involved re flagging and renaming all trees, and brushing of fringing regrowth. Some of the original aluminium plant tags remain intact. The majority of the original wooden pegs with code numbers have gone. There are a few trees that need supporting*...".

Over the past two decades, the Lake Eacham Lauraceae Arboretum site has become overgrown with native woody regrowth species, and dense growth of Wait-a-while (*Calamus* spp.) are common in the understorey and in the canopy. As a result, the site now has the appearance of developing rainforest and is no longer discernible as the original concept. Cursory exploration of the site revealed that much of the original signage has been damaged, lost, or obscured by lichen growth. A few signs are now misrepresentative, as many trees from the original plantings have died.

Towards a new Lake Eacham Lauraceae Arboretum

The current state of the living collection illustrates a disconnection from Tracey and Tucker's original aspirations for the site. Although the plot is adjacent to a widely used walking trail between Lake Eacham Caravan Park, TREAT, and the Lake Eacham recreation area, there is no signage indicating the existence of the arboretum. Excluding local botanists, few know that this rich arboretum of laurels exists. Being close to a known tourist hotspot, a newly branded Lake Eacham Lauraceae Arboretum could play a valuable role in raising public conservation awareness, and in cultivating pro-conservation attitudes and sustainable tourism (Ballantyne *et al*. 2008). We resonate with, and aim to expand on, the early aspirations of Tracey and Tucker to preserve a national heritage of laurels and to create a space for visitors to learn about one of Australia's largest rainforest families. To carry out these goals, we (1) conducted a detailed survey of the plot to re-identify and map original plantings, and to examine the condition of the plantings, (2) tag and measure the remaining plantings to obtain new baseline data for future monitoring, and (3) make recommendations for management of the woody regrowth vegetation for better growth and development of the planted trees and for public accessibility and safety.

Methods

In order to catalogue and map surviving individuals, we established a grid system composed of 10 m x 10 m subplots in the area containing the original laurel plantings. We selected a starting point (QPWS Rainforest Display Centre signage) and commenced by measuring out ten meters in each cardinal direction using a compass and transect measuring tape. Once a 10 m x 10 m

subplot was established, subplot corners were staked with 40 cm polyethylene pipes spray-painted bright orange, and string was used to delineate the subplot perimeter. This process was iterated to create additional subplots with y-axes running north-south and x-axes east-west until all planted laurels were encompassed in a system of grid square subplots. We labelled these subplots starting from the southwest corner with A0 and continuing north numerically and east alphabetically.

Local botanists Dr. David Tng and Gemma Horner re-identified and distinguished laurels from the surrounding regrowth using the original planting layout (Fig. S1) as a working guide to find the approximate planting locations. Each individual laurel was then labelled with a new number, using wire and aluminium tags. The wires were tied around the trees loosely, and in such a fashion that would allow the trees to grow without any constriction. To facilitate relocating trees in future monitoring, we also recorded the x and y coordinates of each tree within each 10 m x 10 m subplot. The diameter at breast height (1.3 m) of each stem was then recorded by measuring tape, and the height of each stem estimated.

Data analysis

Using the coordinates, laurels were mapped onto the grid squares in which they occurred, and sorted according to genus and species. While compiling the laurel species found at the Lake Eacham Lauraceae Arboretum, we also tabulated species which are represented in living collections at Cairns Botanic Gardens, Cooktown Botanic Gardens (Cook Shire Council 2015) and the ex-CSIRO arboretum. Laurel species occurrence at the Cairns Botanic Gardens was compiled from the Tree Plotter website (*https://au.pg-cloud.com/Cairns/*) and for the ex-CSIRO Arboretum at Atherton using an arboretum guide prepared by previous staff at CSIRO (CSIRO 2020).

Results

We established a total of 68 10 m x 10 m grids (0.68 ha) within the original laurel planting site (Fig. 2) in which 164 individual trees belonging to 59 laurel species were mapped (Table 1). This represents 69.4% of the original species planted in the 1980s (Table 1). Nineteen of these trees were multi-stemmed, so we tagged and measured 196 stems in total. The largest tree measured was

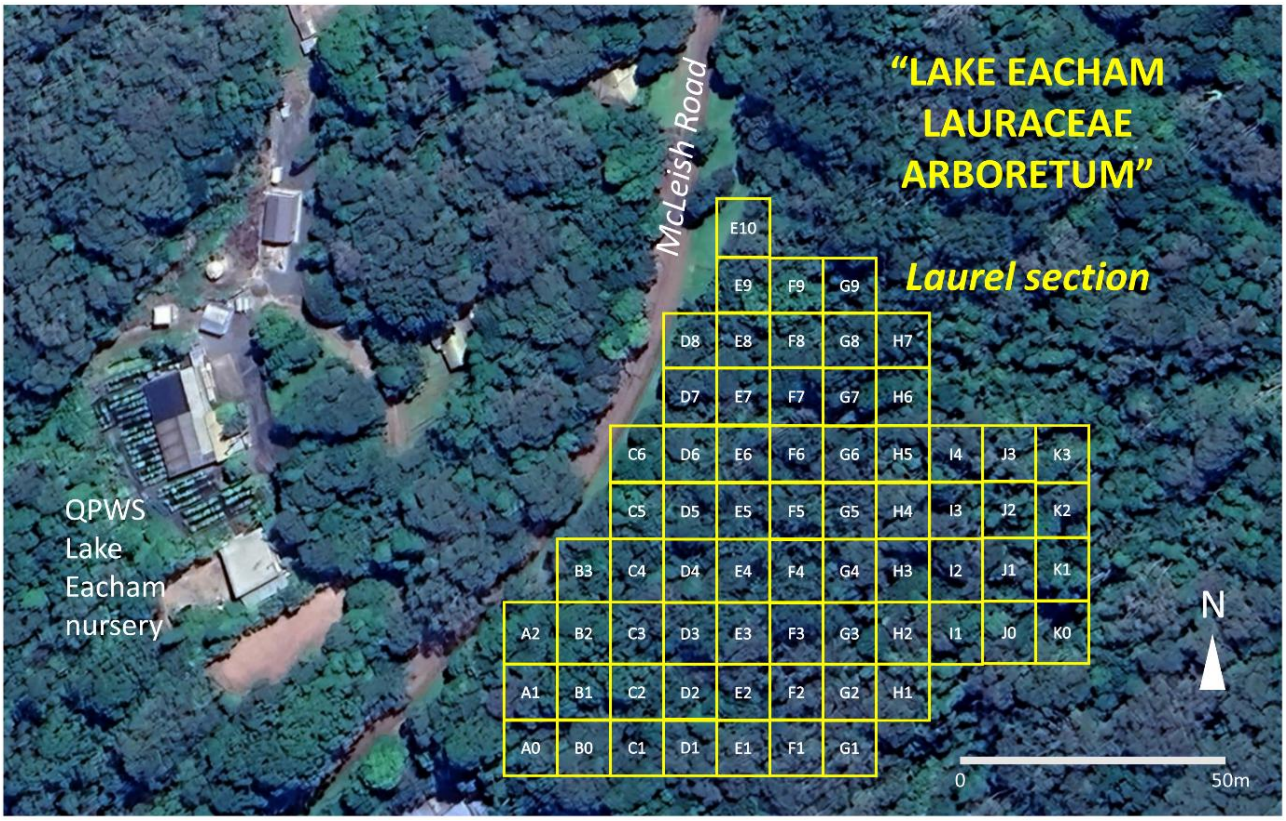

Figure 2. Grid mapping system within the Lauraceae section of the Lake Eacham Lauraceae Arboretum. This comprised 68 subplots, each of 100 m^2. Yellow lines represent subplot borders. Adjacent is McLeish Rd, Lake Eacham Qld, with the QPWS Lake Eacham nursery indicated.

Table 1. List of laurels planted in the Lake Eacham Lauraceae Arboretum in the 1980s and their presence in subsequent censuses in 1997 and the in the current study in Nov. 2023.
Known laurel occurrences in the Cairns and Cooktown Botanic Gardens and the ex-CSIRO arboretum in Atherton are listed for comparison. Distribution codes are follows: CYP – Cape York Peninsula, NEQ – Northeast Queensland, CEQ – Central Eastern Queensland, SEQ, Southeastern Queensland, NSW – New South Wales, NT – Northern Territory, WA – Western Australia.

Species planted	Previously planted at the Lake Eacham Laurel Arboretum	Located again in 1997	Located again in 2023	Known collection in Cairns Botanic Gardens	Known collection in Cooktown Botanic Gardens	Known collection in ex-CSIRO arboretum	Distribution
Beilschmiedia bancroftii	1	1	1	0	0	0	NEQ
Beilschmiedia brunnea	1	1	1	0	0	0	NEQ
Beilschmiedia castrisinensis	1	1	0	0	0	0	NEQ
Beilschmiedia collina	1	1	0	0	0	0	NEQ, CEQ
Beilschmiedia obtusifolia	1	1	1	0	0	1	CYP, NEQ, CEQ, central NSW
Beilschmiedia oligandra	1	1	1	0	0	0	NEQ
Beilschmiedia peninsularis	1	1	1	0	0	0	CYP
Beilschmiedia recurva	1	1	1	0	0	0	NEQ
Beilschmiedia volckii	1	1	0	0	0	0	NEQ
Cinnamomum baileyanum	0	0	0	0	0	1	CYP, NEQ, SEQ
Cinnamomum laubatii	1	1	1	0	0	0	NEQ, CEQ
Cinnamomum oliveri	1	1	0	0	0	1	CYP, NEQ, CEQ, SEQ, southeastern NSW
Cinnamomum virens	1	0	0	0	0	0	SEQ, NSW
Cryptocarya angulata	1	1	1	1	0	0	NEQ, CEQ
Cryptocarya bamagana	1	1	0	0	0	0	CYP
Cryptocarya bellendenkerana	1	1	1	0	0	0	NEQ
Cryptocarya bidwillii	1	0	0	0	0	1	NEQ, CEQ, northeastern NSW
Cryptocarya brassii	1	1	1	1	0	0	CYP
Cryptocarya burckiana	1	0	0	0	0	0	CYP, Malesia
Cryptocarya clarksoniana	1	1	1	1	0	1	NEQ
Cryptocarya claudiana	1	1	1	0	0	1	CYP
Cryptocarya cocosoides	1	1	1	0	0	1	NEQ
Cryptocarya corrugata	1	1	1	0	0	1	NEQ, CEQ
Cryptocarya cunninghamii	1	1	1	0	0	1	WA, NT, CYP, NEQ
Cryptocarya endiandrifolia	1	0	0	0	0	0	CYP, NEQ, New Guinea
Cryptocarya erythroxylon	1	1	0	0	0	0	SEQ, NSW
Cryptocarya exfoliata	1	1	1	0	0	1	NT, CYP, NEQ
Cryptocarya glaucescens	1	1	1	0	0	0	CEQ to southeastern NSW
Cryptocarya glaucocarpa	0	0	0	0	0	1	CYP
Cryptocarya grandis	1	1	1	0	0	1	CYP, NEQ, CEQ
Cryptocarya hypospodia	1	1	1	1	1	1	NT, CYP, NEQ, CEQ to SEQ
Cryptocarya laevigata	1	1	1	1	0	1	NEQ, SEQ, northeastern NSW, Malesia
Cryptocarya leucophylla	1	1	1	0	0	0	NEQ, CEQ
Cryptocarya lividula	1	1	1	0	0	1	NEQ

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Table 1 continued

Species planted	Previously planted at the Lake Eacham Laurel Arboretum	Located again in 1997	Located again in 2023	Known collection in Cairns Botanic Gardens	Known collection in Cooktown Botanic Gardens	Known collection in ex-CSIRO arboretum	Distribution
Cryptocarya macdonaldii	1	1	1	0	0	0	CEQ, SEQ
Cryptocarya mackinnoniana	1	1	1	0	0	1	CYP, NEQ, New Guinea
Cryptocarya melanocarpa	1	1	1	0	0	1	NEQ
Cryptocarya murrayi	1	1	1	1	0	1	NEQ, CEQ
Cryptocarya oblata	1	1	1	0	1	0	NEQ
Cryptocarya obovata	1	0	0	0	0	0	SEQ and NSW
Cryptocarya onoprienkoana	1	1	1	0	0	1	NEQ, CEQ, southeastern NSW
Cryptocarya pleurosperma	1	0	0	0	0	0	NEQ
Cryptocarya putida	1	1	1	1	0	0	NEQ, CEQ
Cryptocarya rhodosperma	1	1	1	0	0	1	CYP, NEQ
Cryptocarya smaragdina	1	1	1	0	0	0	NEQ
Cryptocarya triplinervis var. *triplinervis*	1	1	0	0	0	0	CEQ, northern NSW
Cryptocarya triplinervis var. *riparia*	1	1	1	0	0	1	CYP, NEQ
Cryptocarya vulgaris	1	1	1	0	0	0	CYP, NEQ, CEQ to central coastal QLD
Cryptocarya williwilliana	1	1	1	0	0	0	NSW
Endiandra acuminata	1	1	1	0	0	0	NEQ
Endiandra anthropophagorum	0	0	0	1	0	0	NEQ
Endiandra bellendenkerana	1	1	1	0	0	0	NEQ
Endiandra bessaphila	1	1	1	0	0	0	NEQ
Endiandra compressa	1	1	1	0	0	1	CYP, NEQ, CEQ, northeastern NSW
Endiandra cooperana	1	1	1	0	0	0	NEQ
Endiandra cowleyana	1	1	1	1	0	1	CYP, NEQ, CEQ
Endiandra dielsiana	1	1	1	0	0	0	CYP, NEQ, CEQ, New Guinea
Endiandra discolor	1	1	1	0	0	0	NEQ, CEQ to coastal central NSW
Endiandra glauca	1	0	0	0	1	0	CYP, NEQ, New Guinea
Endiandra globosa	1	1	1	1	0	0	NEQ, SEQ, northeastern NSW
Endiandra grayi	1	1	1	0	0	1	NEQ
Endiandra hypotephra	1	1	1	0	0	1	NEQ, CEQ
Endiandra impressicosta	1	1	0	1	0	1	CYP, NEQ, New Guinea
Endiandra jonesii	1	1	1	0	0	0	NEQ
Endiandra leptodendron	1	0	0	0	0	0	NEQ
Endiandra longipedicellata	1	1	1	0	0	1	CYP, NEQ
Endiandra microneura	1	1	1	1	0	1	NEQ

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Table 1 continued

Species planted	Previously planted at the Lake Eacham Laurel Arboretum	Located again in 1997	Located again in 2023	Known collection in Cairns Botanic Gardens	Known collection in Cooktown Botanic Gardens	Known collection in ex-CSIRO arboretum	Distribution
Endiandra monothyra ssp. *monothyra*	1	1	1	0	0	0	NEQ
Endiandra monothyra ssp. *trichophylla*	1	1	0	0	0	0	NEQ
Endiandra montana	0	0	0	0	0	1	NEQ, New Guinea
Endiandra palmerstonii	1	0	0	0	0	1	NEQ
Endiandra phaeocarpa	0	0	0	0	0	1	NEQ
Endiandra pubens	1	1	0	0	0	0	SEQ, northern NSW
Endiandra sankeyana	1	1	1	1	0	1	NEQ
Endiandra sideroxylon	1	1	1	0	0	0	NEQ
Endiandra sieberi	1	0	0	0	0	0	CEQ, SEQ, NSW
Endiandra wolfei	1	1	1	0	0	0	NEQ, CEQ
Lindera queenslandica	1	1	0	0	0	0	CYP, NEQ, ?New Guinea
Litsea australis	1	1	1	0	0	0	SEQ, northern NSW
Litsea bennettii	1	1	0	0	0	0	NEQ
Litsea bindoniana	1	1	1	0	0	0	NEQ, CEQ
Litsea breviumbellata	1	1	1	0	0	1	NT, CYP, NEQ, CEQ, New Guinea
Litsea connorsii	1	1	1	0	0	0	NEQ
Litsea fawcettiana	1	1	1	0	0	1	CYP, NEQ, CEQ, SEQ
Litsea granitica	1	0	0	0	0	0	NEQ
Litsea leefeana	1	1	1	0	0	1	NEQ, CEQ, SEQ
Litsea macrophylla	1	1	0	0	0	0	CYP
Neolitsea brassii	1	1	0	1	0	1	CYP, NEQ, CEQ, SEQ, New Guinea
Neolitsea dealbata	1	1	1	0	0	1	CYP, NEQ, CEQ to southeastern NSQ
Total	84	73	59	14	3	37	

Cryptocarya rhodosperma, which had a diameter of 38.2 cm. We also tagged a Brown Magnolia (*Galbulimima baccata*) (Himatandraceae), not a member of Lauraceae family, but present in the plot and represented with signage.

The 59 species were composed of six genera; *Beilschmiedia* (6 spp.), *Cinnamomum* (1 spp.), *Cryptocarya* (27 spp.), *Endiandra* (18 spp.), *Litsea* (6 spp.), and *Neolitsea* (1 spp.) (Fig. 3). Notably, *Cinnamomum* is only represented in the arboretum by one individual specimen of *Cinnamomum laubatii*. The genus *Lindera* (which is represented by the single species *L. queenslandica*) was originally planted but was not found in this review nor the 1997 census. Despite the reduction in species, the Lake Eacham Arboretum still exceeds the Cairns Botanic Gardens, Cooktown Botanic Gardens and the ex-CSIRO arboretum respectively by 45, 56 and 22 species of laurels.

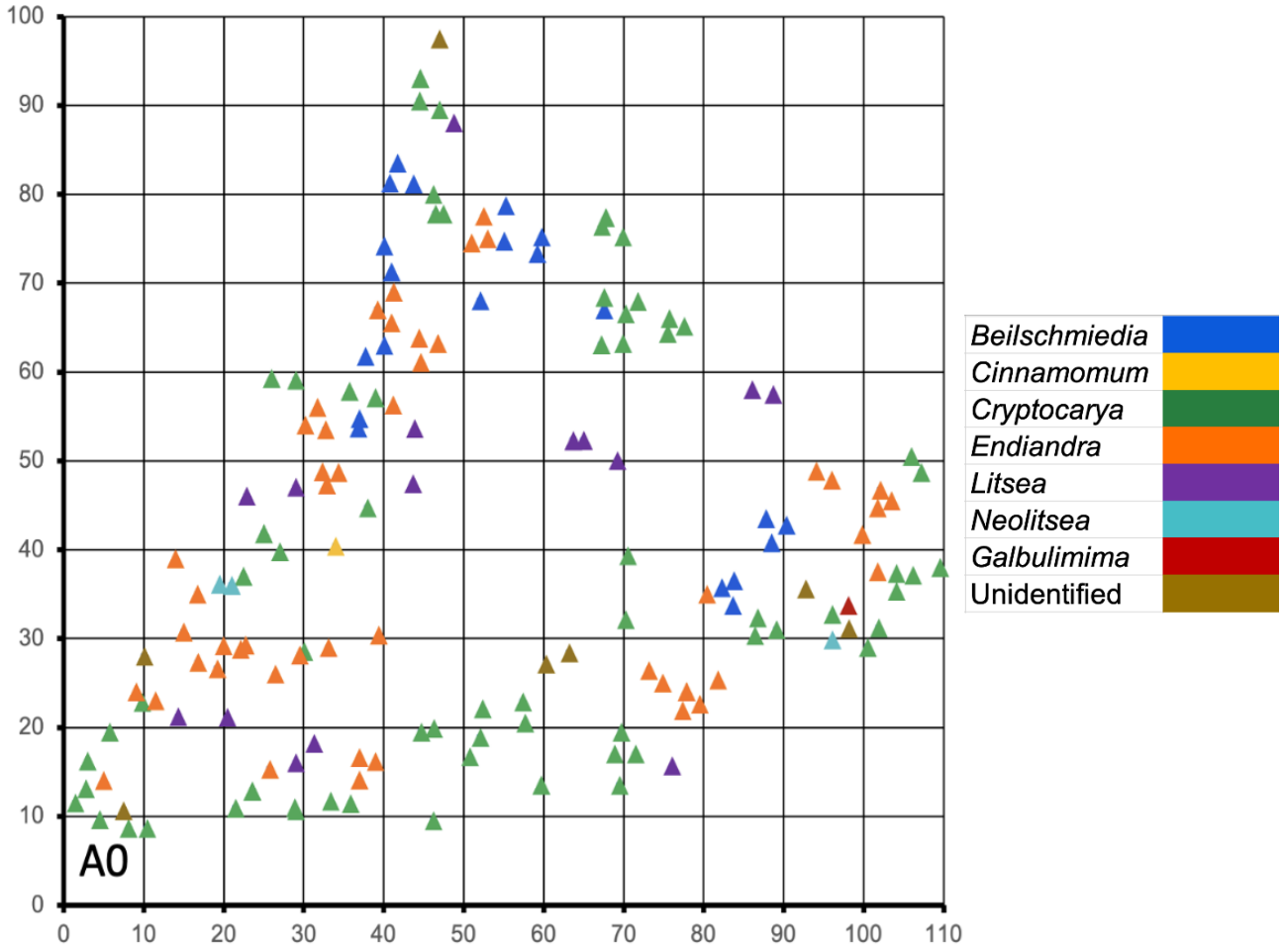

Figure 3. Coordinate system depicting the relative location of 164 individual laurels in the laurel section of the Lake Eacham Lauraceae Arboretum, sorted by genera.
Each square represents an established 10 m by 10 m subplot; the origin is the southwestern corner of subplot A0. Triangles represent individual specimens, while colours correspond to genera.

It was not possible to reliably match the trees with their original numbers because none of the original number tags remained. The individual laurels are now labelled from 1–164 with aluminium tags in order to help with future identification. Four specimens could be positively identified as laurels but could not be narrowed down to species.

Discussion

We conducted a census of the Lauraceae specimens which were originally planted at the Lake Eacham Lauraceae Arboretum in 1984-88 and found that 59 of the 84 species were still present. Despite the diminished state of the original plantings, it is still the largest known living collection of native laurels in Australia. Laurels currently featured in the arboretum encompass species found in a range of rainforest types, and which also occur in different regions (Western Australia, Northern Territory, Cape York Peninsula, Wet Tropics, Central east Queensland, Southeast Queensland and also New South Wales). Some species endemic to the Wet Tropics and with very narrow home ranges were also represented, such as *Endiandra grayi* (Fig. 4A) and *E. microneura* from the Daintree, and *Cryptocarya bellendenkerana* and *E. bellendenkerana* from the Mt. Bellenden Ker region. Being also home to much of the type material used in Hyland's (1989) revision and description of new species, the scientific value of this living collection is considerable.

Nevertheless, the concerning trend of decline in the original plantings needs to be addressed urgently. The loss of seven species since the last census in 1997 (Table 1) and a total of 25 species since the original plantings is lamentable. Moreover, only 164 individual laurels were located,

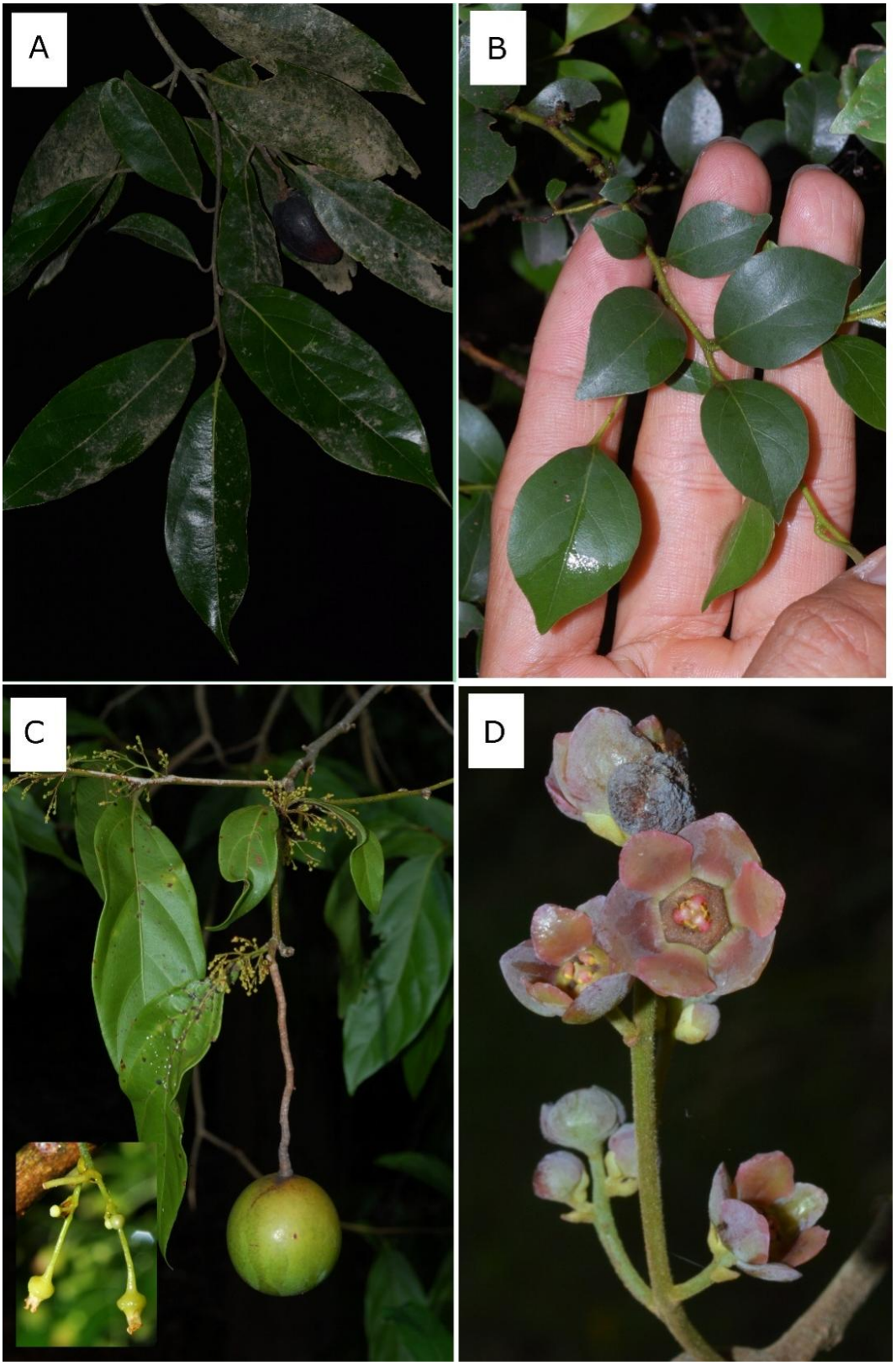

Figure 4. Representatives of members of the Lauraceae native to Queensland.
A, *Endiandra grayi*, a narrow endemic in the lowlands of the Daintree, north Queensland. **B**, *Cryptocarya williwilliana*, a species from New South Wales that is more adapted to drier environments. Note the small leaves. **C**, *E. anthropophagorum*, a north Queensland species that was not represented in the original plantings at Lake Eacham, but planted in Cairns Botanic Gardens. Inset shows a closeup of the flowers. **D**, The unusually reddish flowers of *E. hypotephra*, a widespread species in the Wet Tropics.

compared to 209 individuals in the 1997 census (a 21.5% reduction), and the 301 that were originally planted (a 45.7% reduction). These reductions are most likely caused by natural ecological processes, including cyclones and natural regeneration, along with a lack of site maintenance over the past two decades.

Natural regeneration increasingly dominates the site. We noticed numerous early successional species including *Acacia* spp., *Alstonia muelleriana*, *Eucalyptus grandis*, *Mallotus paniculatus* and *Polyscias* spp. with collective stem densities well exceeding the planted laurels. These species are casting shade over plantings and this, combined with root competition, is suppressing the growth of plantings. *Acacia celsa* and *E. grandis* also develop branches that snap easily and are likely to have damaged plantings. In some areas, dense growths of climbing palms *Calamus australis* or other vines are suppressing some planted stems.

The physical condition of many of the laurels is also a matter of concern. For instance, the single living specimen of *Cryptocarya williwilliana* (Fig. 4B) had a dead main stem and was surviving in the form of a few 20 cm tall coppice shoots at the base of the dead stem. This species should be given priority for management, along with others represented by only one individual (*Beilschmiedia oligandra*, *Cryptocarya bellendenkerana*, *C. cocosoides*, *C. cunninghamii*, *C. oblata*, *C. rhodosperma*, *Endiandra bellendenkerana*, *E. discolor* and *E. wolfei*; Table 1). For some other species, the original specimens have died, but we fortuitously located their regenerating saplings; younger specimens need additional protection given their vulnerable sapling stage. Some of the species represented are rare or occur in locations with restricted access, and thus maintenance of the existing specimens in the arboretum is important. Without appropriate intervention, we believe that many of the original laurel plantings will continue to decline.

It may now be worthwhile to augment the collections with laurel species no longer present, and also plant species not originally planted or newly described species. For the first purpose, representatives of the genus *Cinnamonum* and *Lindera* should be prioritized. Other refill plantings in the short term could also focus on species such as *Cryptocarya pleurosperma*, *Endiandra palmerstonii*, and *Neolitsea brassii*, which are relatively easy to locate in native forests nearby. It is noteworthy that the Cairns Botanic Gardens and the ex-CSIRO collection contain a number of species (*Cinnamomum baileyanum*, *Cryptocarya glaucocarpa*, *Endiandra anthropophagorum* [Fig. 4C], *E. montana*, and *E. phaeocarpa*) that were not represented in the original plantings at the Lake Eacham Lauraceae Arboretum. Seeds or seedlings could potentially be sourced from these sites for planting at the arboretum.

We also noticed while conducting the survey that some species were very fecund, and numerous seedlings could be found at the base of parent trees. This was not surprising for widespread species such as *Endiandra hypotephra* (Fig. 4D), *Litsea leefeana*, and *Neolitsea dealbata*, which also occur naturally in nearby forests. Curiously, we also notice very high intensities of seedlings under a parent tree of the uncommon Daintree endemic *Endiandra grayi*, which is a lowland species. Seeds and seedlings of such highly productive species could be harvested and raised at the QPWS Nursery and be redistributed for use in rainforest restoration initiatives in the region.

Steps moving forward

The Lake Eacham Lauraceae Arboretum is situated in a convenient and well-visited locality and can provide excellent public education for local and international visitors. As laurels are notoriously difficult to identify, the living collections could serve as an unparalleled resource for botanists and scientists to study the Lauraceae family. Now that the remaining laurels have been located, labelled, and mapped onto a systematic grid system, we believe that this groundwork will significantly enhance the value, accessibility and utility of the living collection.

Although this project has set the foundations of a larger restoration project for this arboretum, substantial work will need to be done before this living collection will be accessible and attractive to the public. The first step would be to remove successional species that have regenerated within the site, preferably using an elevated work platform to minimise damage to planted stems. This crucial step should be done under supervision by knowledgeable land managers or botanists, as there are many laurel seedlings and saplings that should be left uncut.

The next step would be to construct a trail through the arboretum (Fig. S2), which could be either a

gravel path or even a boardwalk for disability access. This would require careful planning of a trail system so that laurel plants are not damaged in the process. Following implementation of the trail, an interactive digital map using GIS software can be created which visitors may use to navigate the arboretum. The map may contain additional information about the arboretum such as cultural input for traditional landowners, more species-specific facts, and a more detailed distribution of laurel genera, and ecology.

In addition to clearing the woody understorey and constructing a trail, the old signposts that still remain from the original plantings in the 1980s should be replaced, as many have deteriorated and some feature inaccurate information. The individual trees could be labelled with their binomial names on the more modern and durable metal labels now used routinely in botanic gardens. An innovative way to facilitate public education would be to match signage with QR codes which when scanned will take visitors to descriptions and coloured photos with flowers and fruits of the laurel species being observed (Fig. S2). Once the walking trail and map are established, new signage will need to be created to guide visitors through the arboretum with appropriate educational materials.

Increasing public knowledge about this arboretum will be paramount, which we hope is achieved in part by this article. Currently, there are only a few local botanists and QPWS rangers who are aware of the living collection, and no signage indicates its existence. By advertising its presence during and upon completion of this project, the educational objectives of this site are more likely to be successfully met. Such advertisements could take the form of posters in the local towns of Yungaburra and Atherton or at the popular recreational site of Lake Eacham. They could also include informational brochures about the arboretum in the Rainforest Display Centre located just across McLeish Road from the site. The arboretum could also be advertised on high-traffic websites that promote visitor destinations in the region, such as those of the Wet Tropics Management Authority and Tablelands Regional Council.

Conclusion

In conducting a census of a little known and neglected living collection of Lauraceae at Lake Eacham, we found that the native laurel diversity is still substantial three decades after the initial planting. Such arboreta not only provide opportunities for scientific research, public education, and the growth of local ecotourism, they can also accomplish ex-situ conservation of rare species, and be a seed source for local restoration efforts (Hardwick *et al.* 2011). There is huge potential for the laurel planting to be expanded into a fully functional and public arboretum due to the relative ease of linking the arboretum to existing trails in the Crater Lakes National Park. Due to the significance of these living collections, The School for Field Studies will be working with The Queensland Parks and Wildlife Service alongside First Nations people to establish a new name for the site. We are proposing "Botanical Ark Arboretum". Future work should also aim to map, tag and identify the smaller collections of Moraceae, Myrtaceae and Proteaceae that are in the vicinity of the laurel plantings, so that these collections may be integrated into an expanded database.

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Supplementary file

A supplementary pdf file accompanies this paper on its web-page. It contains:

- Fig. S1. Original laurel planting layout (1984-1988); and
- Fig. S2. Proposed template for a welcome sign to the arboretum.

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