

Threat specific contingency plan for Dutch Elm Disease

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Disclaimer

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1 Role of EPPRD and PLANTPLAN¹

Australia is fortunate to be free of many of the world's most destructive plant pests that are common elsewhere; a benefit that confers significant advantage to Australian agriculture. An Emergency Plant Pest (EPP) Incident could cause serious production losses, jeopardise exports of plant and plant products or have serious implications to the environment, amenity values or regional communities.

To effectively respond to an EPP Incident, a formal and legally binding agreement – the Emergency Plant Pest Response Deed (EPPRD) – has been agreed between Plant Health Australia (PHA), the Australian Government, all state and territory governments and national plant industry peak body signatories (EPPRD Parties). The EPPRD covers the management and funding of responses to EPP Incidents, including the potential for Owner Reimbursement Costs (ORCs) for Owners, and formalises the role of Parties in decision making as well as their contribution towards the costs. Under the EPPRD, beneficiaries of the eradication of an EPP pay an appropriate and equitable proportion to the costs of mounting a response, based on an assessment of the relative and public benefits of eradication.

PLANTPLAN is the generic national response plan underpinning the EPPRD primarily concerned with the eradication of EPPs which pose a potential threat to Australia's agricultural industries. PLANTPLAN provides nationally consistent guidelines for managing a response to an EPP Incident at national, state/territory and local levels, describing the national procedures, management structures and information flow systems.

Pest-specific contingency plans are resource documents designed to assist with Australia's planning and preparedness for EPP's, but are not a formal component of the EPPRD. They provide background information on the biology of a specific pest and the control measures currently available to assist with preparedness activities in the event of an EPP Incident, along with guidelines and options for steps to be considered and undertaken when developing a Response Plan. Contingency plans are developed by PHA, government and industry and a number are available from the PHA website (www.planthealthaustralia.com.au/pidd).

2 Purpose and background of this contingency plan

This contingency plan provides background information on pest biology and available control measures to assist production nurseries with preparedness for an incursion into Australia of Dutch elm disease (caused by *Ophiostoma* spp.). It provides guidelines and options for steps to be undertaken and considered when developing a Response Plan to this pest. Any Response Plan developed using information in whole or in part from this Contingency Plan must follow procedures as set out in PLANTPLAN and be endorsed by the National Management Group prior to implementation. This contingency plan was developed for the Nursery & Garden Industry Australia (NGIA) and is focused on production nurseries. In the event of an incursion, operations not covered by the NGIA (e.g. retail outlets) will not be

¹ From PLANTPLAN 2016.

eligible for Owner Reimbursement Costs, as defined in the Emergency Plant Pest Response Deed, if affected by actions carried out under an approved Response Plan.

The information for this plan has been primarily obtained from “Australian Dutch Elm Disease Contingency Plan” compiled and edited by Greg Lefoe, Gordon Berg and David Beardsell (DNR&E Victoria) in 2001. Modifications have been made to the plan to make the information relevant to an incursion of DED in the nursery industry as per recommendations. As such, this document is designed as an amendment to Lefoe *et al.* (2001) dealing with the nursery industry specifically. These documents should be used together in the event of an incursion.

In addition, at the time that this contingency plan was completed, the diagnostic protocol for *Ophiostoma* spp. written by Yu Pei Tan (DAF) had not been formally published. It is therefore referred to Tan (unpublished) throughout the document. A copy of this draft can be obtained through the SPHD secretariat.

Please note that elm bark beetles refers to *Scolytus* spp. generally. The scientific name of each beetle species is used for information pertaining to only one species.

3 Critical tasks

There are a number of areas which will require careful planning or implementation following the detection of Dutch elm disease (DED) that are not covered in this contingency plan. These tasks include (but are not limited to):

- Determine if DED is notifiable as per the state/s legislation.
- Identify diagnostic laboratories capable of promptly examining elm material with DED-like symptoms.
- Establish a register of all elm production nurseries and record the elm trees in their proximity.
- Determine if additional surveillance or biosecurity activities are required within BioSecure HACCP to mitigate the risk of DED entering elm production nurseries.
- Compile a list of retail outlets selling elms within and near quarantine areas.
- Prepare fact sheets and posters as part of the communication/education strategy. A DED factsheet for production nurseries will be produced in 2016 under the HIA project NY15002.
- Define a surveillance program for early detection. Components of this program should include sourcing a supplier for elm bark beetle pheromone traps (see Appendix 4) and complete extensive trapping for a range of vector species. Determining the lead time taken for traps to arrive in Australia and/or the time lures remain viable would be required to evaluate whether a stockpile of traps with lures would be a useful preparedness activity.

- Determine if preparedness activities are required that will assist/inform control of vectors or DED. This could include determining the most effective chemical controls for vectors or the fungal pathogen. Information should be collated on for submission of Emergency Permits for chemical control of vectors or potentially the pathogen.

4 Australian nursery industry

The Australian nursery industry is a significant horticultural sector with a combined supply chain (production to retail/grower) valued at more than \$6 billion dollars annually. The industry employs approximately 45,000 people spread over more than 20,000 small to medium sized businesses, including production nurseries and retail outlets. The industry is located predominantly along the Australian coastline, and in major inland regions servicing urban and production horticulture.

Nursery production adds significant value to Australia's primary industry's sector annually, contributing more than \$2 billion to the national economy. Nursery production is a highly diverse industry, providing a critical service to the broader horticultural sector, valued at \$14 billion within Australia (Table 1).

Table 1. Nursery production supply sectors within Australian horticulture

Production nursery	Horticultural market	Economic value
Container stock ²	Ornamental/urban horticulture	\$2 billion retail value
Foliage plants ¹	Interior-scapes	\$87 million industry
Seedling stock ³	Vegetable growers	\$3.3 billion industry
Forestry stock ⁴	Plantation timber	\$1.7 billion industry
Fruit and nut tree stock ²	Orchardists	\$5.2 billion industry
Landscape stock ¹	Domestic & commercial projects	\$2 billion industry
Plug and tube stock ⁵	Cut flower	\$319 million industry
Revegetation stock	Farmers, government, landcare groups	\$109 million industry
Mine revegetation	Mine site rehabilitation	Value unknown

5 Eradication or containment decision matrix

Production nurseries are important as pathways for the potential entry and spread of Dutch elm disease (DED). Following an outbreak of DED the response needs to be clearly explained, decisive, coordinated and rapidly implemented. Initially it will be assumed that

² Data sourced from Market Monitor

³ Data sourced from Horticultural Handbook 2004

⁴ Data sourced from ABARE 2005

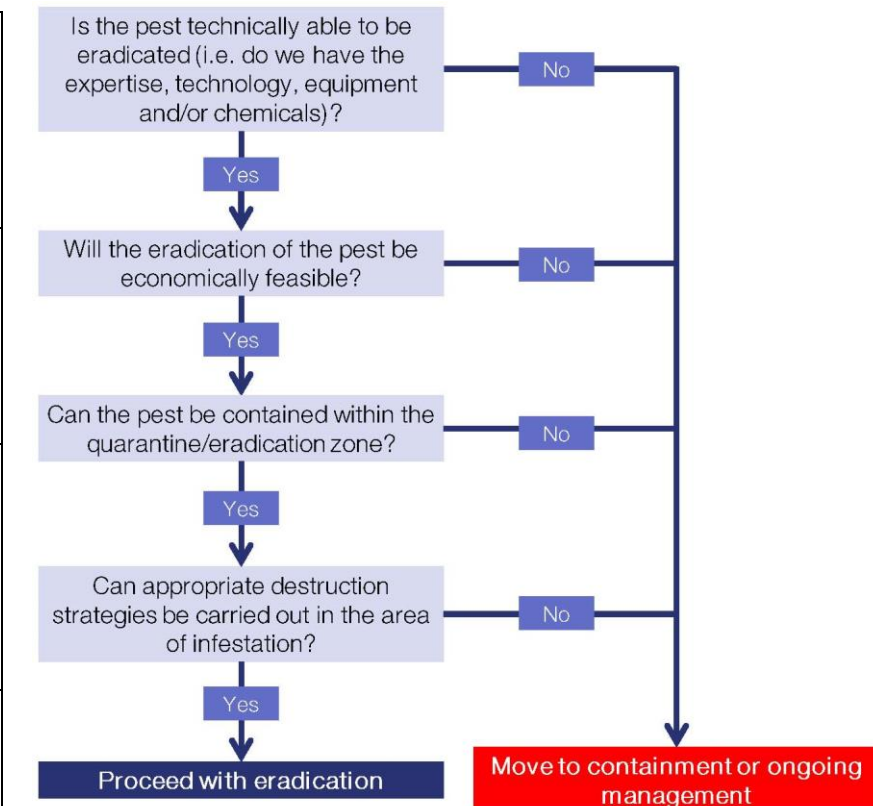
⁵ Data sourced from industry

eradication of DED is possible; containment will be the second option. Containment measures will be based on the biology of the pathogen and its vector, and the institutional and commercial structures in place for the management of plant disease outbreaks.

The decision matrix to aid in the decision between eradication and containment is shown in Figure 1 and Table 2.

Figure 1. Decision outline for the response to an exotic pest incursion and a summary of the basis on which each decision could be

Basis for technical feasibility: ○ Early detection ○ Confined space/restricted area of dispersal ○ Known distribution of host plants ○ Effective, reliable, quick detection method ○ Support from industries, businesses and communities involved.
Basis for economic feasibility: ○ Value of crop destroyed by uncontrolled pest is more than cost of controlling the pest ○ Value of environmental amenity (native species lost) vs cost or loss of other amenity (loss of native insects due to spraying in native forests, etc.)
Basis for quarantine containment: ○ Legislation to create a pest quarantine area (PQA) ○ Resources to maintain the PQA, inspection points, staffing, detection equipment, diagnostics ○ Support of industry and community to make the PQA work
Basis for destruction/control strategies required: ○ How much destruction and or control measures are industry and individuals prepared to undertake? ○ What level of destruction is technically feasible? ○ Do the benefits of destruction outweigh the problems created?
What would containment or ongoing management look like? ○ Is containment feasible? ○ What would ongoing management really mean? ○ Many similar features to eradication, but at less intense / restrictive levels.



made.

Table 2. Factors considered in determining whether eradication or alternative action will be taken for an EPP incident from PLANTPLAN (Plant Health Australia, 2016 Table 2).

a)	the capability to accurately diagnose or identify the EPP.
b)	the effectiveness of recommended control technique options, which are likely to be the most cost-effective in eradicating the EPP.
c)	the ability to remove or destroy all EPPs present by the recommended control techniques.
d)	the ability to remove the EPP at a faster rate than it can propagate until proof of freedom can be achieved.
e)	the recommended control techniques are publicly acceptable (taking into consideration cultural and social values, humaneness, public health impacts, non-target impacts and environmental impacts)
f)	whether Emergency Containment measures have been put in place by the Lead Agency(s).
g)	whether there are controls methods, commonly employed for endemic pests and diseases, that may limit or prevent the establishment or impact of the EPP.
h)	any legislative impediments to undertaking an emergency response.
i)	the resources e.g. chemicals, personnel etc. required to undertake an emergency response are accessible or available.
j)	the ability to delimit the known area of infestation.
k)	the ability to identify the pathway for entry into, and trace the spread of the EPP within Australia.
l)	the ability to determine whether the likelihood of further introductions is sufficiently low.
m)	the dispersal ability of the EPP (that is, whether the EPP is capable of rapid spread over large distances).
n)	the capability to detect the EPP at very low densities for the purpose of declaring freedom, and that all sites affected by the EPP have or can be found.
o)	the ability to put in place surveillance activities to confirm Proof of Freedom for sites possibly infested by the EPP.
p)	whether community consultation activities have or will be undertaken.

Note: In the case of Dutch elm disease, considerable information is already available from overseas research for evaluating the prospects for eradication or containment (including from New Zealand).

6 Pest information/status – Dutch elm disease

6.1 Pest details

Table 3. Taxa associated with Dutch elm disease

Common names	Dutch elm disease
Scientific name	<i>Ophiostoma ulmi</i> , <i>Ophiostoma novo-ulmi</i> subsp. <i>novo-ulmi</i> , <i>Ophiostoma novo-ulmi</i> subsp. <i>americana</i> , <i>Ophiostoma himal-ulmi</i>
Synonyms	<i>Ceratocystis ulmi</i> , <i>Ceratostomella ulmi</i> , <i>Graphium ulmi</i> , <i>Pesotum ulmi</i>

6.1.1 Background

Dutch elm disease (DED), one of the most destructive plant diseases known, is caused by Ascomycete fungi of the genus *Ophiostoma*, which are vectored by specialised bark beetles.

These fungal pathogens are thought to have originated in Asia and have had a dramatic effect on global elm (*Ulmus* spp.) populations. A major pandemic caused by *O. ulmi* started in Europe in 1910 and continued until the 1940s, causing significant losses (Brasier and Buck, 2001). The pathogen was identified in Holland in 1922 – hence its name. Around 1917 it was taken to North America on diseased elm logs. The first pandemic declined in the 1940s, thought to be due to the spread of deleterious fungal viruses in the *O. ulmi* population (Mitchell and Brasier, 1994). This decline did not occur in North America. A second and more destructive pandemic occurred in the early 1970s. This was due to the introduction of another species of the fungus, *Ophiostoma novo-ulmi*, a much more aggressive pathogen than *O. ulmi*. As *O. novo-ulmi* spreads, it is replacing *O. ulmi* (Brasier, 2001). Of particular concern to Australia was the discovery in 1989 of *O. novo-ulmi* infecting elms in Auckland in New Zealand. *O. novo-ulmi* is comprised of two subspecies: *O. novo-ulmi* subsp. *novo-ulmi* (Eurasian race) and *O. novo-ulmi* subsp. *americana* (North American race) (Brasier and Kirk, 2001). A fourth taxon, *O. himal-ulmi*, has been described from elms in the Himalayas. An association with naturally diseased elms has not yet been shown, although artificial inoculation studies have demonstrated its pathogenicity to *U. procera* (Brasier and Mehrotra, 1995).

With DED the emphasis needs to remain on preventing its introduction. Australia has the geographical advantage of being physically isolated and has strict quarantine laws on the entry of plant material that could introduce the DED pathogens. No plants or part of a plant can be imported into Australia from the genera *Planera*, *Ulmus*, and *Zelkova* without a permit granted by the Director of Quarantine. Elms in Australia are an important feature of many urban landscapes, and have considerable amenity value. They are also of heritage significance, often planted in Avenues of Honour to commemorate Australia's fallen soldiers.

6.1.2 Life cycle (DED and bark beetles)

Based on their sexual stage, DED pathogens are placed in the ascomycete genus *Ophiostoma*. When two mating types come in contact, ascospores are produced in perithecia in the bark. When ascospores are discharged they accumulate in sticky droplets that can be spread by beetle vectors. *Ophiostoma* also reproduces asexually. Conidia are formed in clusters on short mycelial branches in the xylem vessels. They are carried in the xylem where they reproduce by budding, and are responsible for spreading the pathogen throughout the tree. In dying or recently dead trees sticky conidia are produced on synnemata in tunnels created by the beetles just under the bark. Beetle vectors can carry these conidia to new elm trees. The only known vector known to be present in Australia is the smaller European bark beetle *Scolytus multistriatus* Marsham. The larger European elm bark beetle *Scolytus scolytus* F., was intercepted at a harbour in Sydney in 1945 only. It is not considered present in Australia (PaDIL website).

The adult female beetle bores through the bark of dead or dying elm trees and creates a tunnel as she feeds. Adults are attracted to dying, stressed or weakened trees, using a blend of volatiles released by damaged or diseased elms to find the host (Santini and Faccoli, 2015). Eggs are laid in the tunnel behind her. The eggs hatch into larvae that begin to feed, creating tunnels at right angles to the maternal tunnel. These tunnels are referred to as a gallery. The larvae pupate and emerge through the bark as adults. Aggregation pheromones are released by individuals that attract more individuals. Larvae develop over about 30 days before pupating in the external part of the sap-wood. Pupae develop over about 2 weeks

before emerging as adults. Overseas bark beetles have two generations per year under good conditions, the first occurring from late spring to late summer. The second generation starts in autumn, larvae overwinter and adults emerge in the following spring. Newly emerged adults feed within young twigs, preferably on the upper part of the crown and may in this way for 2-13 days. After which they fly away and search for a weakened tree in which to lay eggs.

If fungi are present in the tree, the emerging adults carry thousands of sticky conidia on their bodies. As the beetles feed spores are dislodged and deposited in the feeding wounds where they germinate and produce mycelium which grows into the xylem. The mycelium produces millions of conidia that are carried in the xylem sap. The fungi also produce enzymes or perhaps also toxins which kill adjacent parenchyma cells. They also induce hormonal imbalance which results in the formation of tyloses (bladder-like outgrowths of parenchyma cells into the lumen of adjacent vessels in the wood). The blockage of the xylem by these tyloses and gums, produced from cell wall breakdown, causes leaves to wilt, which is characteristic of Dutch elm disease. The death of xylem parenchyma is responsible for the brown longitudinal streaks in the outer sapwood just below the bark.

6.1.3 Dispersal

Vector transmission is the most important means of dispersal of the DED pathogens. DED vectors infect elms when they carry spores from a diseased tree to a healthy tree. There are many elm bark beetles that are potential vectors of DED, but only a few are regarded as significant vectors. *Scolytus scolytus* (larger European elm bark beetle), *S. multistriatus* (smaller European elm bark beetle) and *Hylurgopinus rufipes* (Eichh.) are the most important vectors in the Northern Hemisphere. *Scolytus multistriatus* is the vector in New Zealand. This species has been present in Australia since 1974 and has been collected in the cities of Melbourne, Adelaide and Canberra,

Scolytus multistriatus is somewhat host specific. It has mainly been recorded on *Ulmus* spp., however *Zelkova* spp. may be a host. Larger European elm bark beetle has a wider host range being able to feed on *Ulmus* spp., *Z. carpinifolia*, *Carpinus betulus*, *Fraxinus excelsior* (ash), *Juglans regia* (walnut), *Populus nigra* (black poplar), *Prunus* spp., *Quercus* spp. and *Salix* spp. ([Plantwise Knowledge Bank](#)).

When *S. multistriatus* adults emerge from the bark of diseased elm trees, they fly to nearby elms (usually within 80m) for feeding. If the beetles are infective, the spores of the DED fungus will enter into the vascular tissue through wounds created during feeding. After maturation feeding, adult beetles fly up to 10 km to find a suitable breeding tree (Neumann and Minko, 1985). Female beetles penetrate the inner bark and emit a powerful pheromone which attracts both male and female beetles, and after mating the female beetle lays eggs under the bark in tunnels which have been excavated. As the larvae hatch, each bores a tunnel at right angles to the parent tunnel, forming a characteristic fan shape. Pupation occurs in these galleries and this is followed by the emergence of young adults. The DED fungus can also be spread via root grafts. When elms are growing near each other (as in avenues), grafts may develop between the roots of neighbouring elms; i.e. the roots of the trees fuse together. When the fungus is introduced into a healthy elm through a root graft it can very quickly be distributed throughout the tree in the vascular system. Root graft transmission can result in the rapid loss of an entire avenue of elm trees.

Even when a diseased elm tree is killed, the wood can continue to be a source of beetles and DED spores. Thus the wood must not be stored as a source of firewood. The fungus and the beetle can be transported with elm timber (particularly where bark is retained) used for furniture, wooden packaging material, dunnage or as firewood. Elm flowers (fresh) and bark on timber, chips and handicrafts can also carry the pathogen. Infected nursery stock of Elm, *Zelkova* and *Planera* (including cuttings, scion wood and tissue culture) and seeds can also carry the disease (Lefoe *et al.*, 2001). While not a major infection pathway, contaminated pruning tools or other equipment may contribute to disease spread (Pataky, 2000).

Although soil containing infested elm roots could presumably be a possible infection pathway, there is no available literature indicating that the DED fungi have a saprophytic phase in the soil in the absence of elm root material.

6.2 Host range

Natural infections by DED pathogens have only been found in elms (*Ulmus* spp.) and *Zelkova carpinifolia*, which belong in the family Ulmaceae. *Planera aquatic* (water elm) was found to be susceptible in inoculation studies. Host trees include all the Euro-American native elms such as the American elm (*U. americana*), English elm (*U. procera*), winged elm (*U. elata*), mountain elm (*U. glabra*), Russian white elm (*U. laevis*), slippery elm (*U. rubra*), smooth-leaved elm (*U. minor*), rock elm (*U. thomasi*) and red elm (*U. serotina*).

The Asian elm species (e.g. *U. parvifolia*, *U. pumila*) show high levels of resistance and have been used in breeding programs. In the Northern Hemisphere the introduction of Asian elms and elm hybrids has renewed interest in elms in the urban landscape.

6.3 Current geographic distribution

The DED pathogens are thought to have originated in Asia. The resistance of Asian elms to the disease and the discovery of the closely related fungus *Ophiostoma himal-ulmi* in *Ulmus wallichiana* from the Himalayas tend to support this view. However natural populations of DED fungi have not been found in indigenous elm communities in Asia.

O. ulmi occurs in North America, across Europe including Russia, Ukraine, Turkey, the Caucasus and Uzbekistan, but is rapidly facing extinction in the wake of the more aggressive species *O. novo-ulmi*.

O. novo-ulmi is widely distributed in North America, across Europe including Russia, Ukraine, Turkey, the Caucasus and Uzbekistan and New Zealand. *O. novo-ulmi* subsp. *americana* is only known from North America and New Zealand, whereas *O. novo-ulmi* subsp. *novo-ulmi* is found in Central Europe through to Central Asia. Hybrids between these two subspecies are appearing widely in Western Europe where their ranges overlap (Brasier and Buck, 2001).

The current distribution of *O. ulmi* and *O. novo-ulmi* is detailed in CABI (2016a,b)⁶.

⁶ <http://www.cabi.org/isc/datasheet/12165>; <http://www.cabi.org/isc/datasheet/37594>

6.3.1 Potential distribution in Australia

The elm population in Australia consists mainly of DED susceptible species and a major beetle vector, *S. multistriatus* (Smaller European or European elm bark beetle), is present in Australia. It has been collected from the cities of Melbourne, Adelaide and Canberra only. These collection records are old and the distribution of elm bark beetles in Australia may have increased. Most elm plantings have occurred in south-eastern Australia including the states of Victoria, Tasmania, South Australia, New South Wales and ACT. Many elm stands consist of ageing trees, with little genetic diversity, planted in avenues with extensive root grafting. In Australia elms are known to live for approximately 150 years (Tumut Shire Council, 2016), and some elms in Europe have been reported to live up to 250 years and occasionally up to 350 years (Spencer *et al.*, 1991). Many Avenues of Honour were planted in Australia to commemorate those who served and died in World War 1. Thus the potential for rapid spread of the pathogen by root grafts and beetle vectors is high. Elms are relatively uncommon in Queensland and Western Australia. The disease has the potential to spread wherever elm trees are; spread will be facilitated by high populations of the *S. multistriatus*, and by the movement of infected elm material (e.g. nursery stock) from one area to another.

6.4 Symptoms

Dutch elm disease is a vascular wilt disease. Symptoms vary depending on whether trees were infected through beetle feeding wounds, or infected through root grafts. Where beetles are involved trees show wilting, curling and yellowing of leaves on one or more branches in the top of the tree. Large trees may survive and show progressively more symptoms for one or more years. Frequently, by the time symptoms are first noted, the fungus has already reached scaffold branches or the trunk of the tree.

With trees infected through root grafts, symptoms may first appear on the lower crown on the side nearest the graft. The entire crown will soon be affected and trees quickly die.

A typical internal symptom is the presence of brown longitudinal streaks in the outer sapwood of infected branches. This can be seen by peeling off the bark of a dying limb.

In highly susceptible elms, death can occur in a few weeks. Others can survive for years after infection. The response to infection depends on the species or cultivar, on the age and vigour of the tree and the time of the year when infection occurs.

There is very little information available specifically on symptoms of DED in young trees or seedlings, although glasshouse studies conducted by Richards and Takai (1984) revealed wilting and curling of leaves within a week of inoculation, with the majority of leaves curled and browned at the end of the 5 week inoculation period. Inoculated seedlings exhibited stunted growth and internal discolouration of xylem tissue. The severity of symptom development varied with the isolate used for inoculations.

DED symptoms in elm nursery stock and young field grown trees are shown in Figure 2. Additional images of DED symptoms in elms can be found in the NGIA factsheet “Dutch elm disease – a biosecurity threat to Australian elm trees” (Pegg and Manners, 2016).

There are a number of diseases of elm species which exhibit symptoms similar to DED, such as bacterial wetwood, Dothiorella wilt, phloem necrosis and Verticillium wilt. These are described in the draft National Diagnostic Protocol for DED (Tan, unpublished).



Figure 2: DED symptoms in elm nursery stock (left – Photo by Benjamin Held, Dept. of Plant Pathology, University of Minnesota) and in a young field grown tree (right – Photo by Chad Giblin, Dept. of Forestry Research, University of Minnesota).

6.5 Social impact

The DED pathogens have been moved by man to infest Europe and Northern America, where the fungus and the elm bark beetles came together. Elm trees have died by the millions. This epidemic has come to be regarded as one of the most significant events in urban forestry as elm trees had become a premier tree planted in urban landscapes in European and in North American cities. Cities treasured their elm trees and their loss had an enormous social impact on communities. Many communities have made a huge effort to save their elm trees, many of which had been planted in avenues along streets and walkways, in parks and private gardens. Many organizations (e.g. STOPPED in Alberta, Canada; The Friends of the Elms Inc., Victoria, Australia) have been formed to raise awareness of the importance of elm trees and to maintain an active program to exclude or

manage DED. Intensive, coordinated management programs can reduce elm losses to an acceptable level.

Australia has one of the finest populations of mature European elm trees remaining in the world. They are found growing in parks and gardens and some city streets are lined with elm trees. These trees have a high landscape and ornamental value. They are also planted in Avenues of Honour, as living memorials to Australian soldiers who did not return home. These have a considerable heritage value having become a major tourist attraction. If any DED fungi were to reach temperate Australia it would have an enormous social impact on many communities.

6.6 Management of DED

Australia has not yet been subjected to DED, although a vector of the disease, *S. multistriatus*, has been present in Australia since 1974. Exclusion of the pathogen from Australia is therefore a key strategy in the management of DED. Failing this, early detection and complete eradication of infected plants will be required. If eradication of DED is not feasible, a containment program may be implemented.

In countries where Dutch elm disease is established, an integrated approach to disease management is normally adopted, involving community surveillance/early detection, sanitation, destruction of root grafts, tree removal, vector management, application of fungicides and replacement of susceptible elms with resistant cultivars.

6.6.1 Early detection, root graft severance, tree removal and sanitation

Early detection of infected trees, root graft severance, tree removal and sanitation are all critical components of DED management. A program involving regular surveillance, rapid felling of infected trees and sanitary disposal of all wood as soon as possible after infection is detected is recommended (CABI, 2016a,b; Jones and Grand, 2001), but must be stringently maintained in order to be effective (Ganley and Bulman, 2016).

In countries where DED is established, severing root grafts between infected and healthy elms, as well as installing root graft barrier trenches, can save many neighbouring trees as part of an integrated disease management program, and can be more cost effective than tree removal. It may also be a useful method for saving trees of high value, although if this approach is taken, diligent inspection of trees several times in the growing season is required. If symptoms eventually develop in a neighbouring tree and the diagnosis is positive for the DED pathogen, then the tree should be removed. In the context of an eradication or containment campaign however, root grafted adjacent trees should be removed along with the infected tree regardless of the outcome of a diagnostic result, as there is a high probability of transmission of the DED pathogen between root grafted trees (Lefoe *et al.*, 2001). The presence of root grafting between adjacent elm trees can be demonstrated by application of a suitable herbicide to the infected tree, followed by observation of herbicide injury in the foliage of adjacent trees (which indicates root grafting). Methods for severing root grafts and trenching are outlined in Lefoe *et al.* (2001).

When infected trees are removed, the wood must be quickly destroyed before elm bark beetle adults emerge to spread the infection (which can occur in just over a month). Stumps

are destroyed using a mechanical grinder or are debarked to at least 20cm below ground level. Any cut elm wood, whether from healthy, dying or dead elms, should be debarked, buried or burnt to discourage colonisation by elm bark beetles and prevent emergence from infested wood.

6.6.2 Vector control

Cultural control measures to reduce suitable habitats for any elm bark beetle includes:

- Maintaining tree health by fertilising, irrigating and avoiding injury to tree trunks and roots.
- Managing other elm diseases and insect pests such as elm leaf beetle, which may affect the health of the tree. Elm leaf beetles are able to defoliate a large elm tree in one summer.
- Removing potential bark breeding sites, such as dead or dying branches, for elm bark beetles.

Elm bark beetles may also be managed using pheromone traps and insecticides, but only as a component of a larger management plan and must not replace sanitation measures.

Based on overseas experience, a range of insecticides may be suitable for the control of elm bark beetles, including synthetic pyrethroids (cypermethrin, esfenvalerate, fluvalinate, permethrin), methoxychlor and chlorpyrifos (Lefoe *et al.*, 2001). More information on these chemicals is provided in Appendix 3.

The most appropriate timing for the application of broad spectrum insecticides against *S. multistriatus* in Victoria is in spring just before leaf burst (September) and after early summer foliage growth (December).

Pheromone trapping of vectors can be used to help estimate population size and identify high risk locations (Haugen, 1998; Gadgil *et al.*, 2000), and the use of trap logs have been shown to reduce the number of bark beetle vectors (Stipes and Campana, 1981). Trap logs need to be treated with an insecticide or debarked and burned (or buried) prior to beetle emergence. Information on sourcing commercially available pheromone traps for elm bark beetles is provided in Appendix 4.

6.6.3 Prophylactic and therapeutic fungicide treatments

In areas where a DED pathogen is present, injections of systemic fungicide have been used to arrest the early stages of infection or to prevent infection of a healthy tree. Generally fungicide treatments will only inhibit the fungus rather than kill it, so symptoms are likely to reoccur, necessitating the use of repeat applications (at maximum intervals of three years) (CABI, 2016a,b). Additional problems include severe wounding at the injection site and phytotoxic effects on leaves. Due to the upward movement of fungicides following injection, they are not effective against infections arising from root grafts (Pataky, 2000). In countries where DED is established, stem injections with fungicides are often restricted to high value trees for economic reasons (Haugen, 1998). Propiconazole and thiabendazole are considered the most effective and well documented fungicides for use against DED (Pataky, 2000). Information on the injection of trees with thiabendazole is detailed in Appendix 3.

6.6.4 Disease resistance

Elm species grown in monoculture (e.g. avenues planted with the same elm species in close proximity to each other) pose a risk for the rapid spread of DED. Increasing diversity of species planted and use of disease-resistant or tolerant species, while not always aesthetically desirable, are important long-term strategies for DED management. Breeding programs in Europe and North America have been undertaken over many years to produce DED-resistant elms (CABI, 2016a,b), and as a result several hybrid and clonal elms are now available that have very good resistance to DED (D'Arcy, 2000).

6.6.5 Biological control

Injection of conidia from a hypovirulent strain of *Verticillium dahliae* into the vascular tissue of healthy elm tissue has shown to be effective in inducing resistance to DED (Scheffer, 1990; Elgersma *et al.*, 1993). The technique has been tested extensively in the Netherlands and USA, and is commercially available in both countries (Voeten, 2003).

Overseas, the use of d-factor viruses have been shown to reduce DED pathogen virulence and spread (Brasier, 1983, 1986, 1996, 2000). They are also considered the most likely biological control agent to meet regulatory requirements, and New Zealand researchers are currently evaluating some of these mycoviruses against *O. novo-ulmi* (Ganley and Bulman, 2016). The potential for this strategy to be successful in New Zealand is considered to be relatively good due to the low genetic diversity and scarcity of the pathogen at the current time. A similar strategy has been proposed in Canada using mitoviruses (Hintz *et al.*, 2013).

6.7 Diagnostic information

A National Diagnostic Protocol (NDP) for DED has been drafted (Tan, unpublished). The protocol provides information on DED symptoms, detection and sampling methods, as well as protocols for the morphological and PCR-based molecular identification of the four DED taxa (*O. ulmi*, *O. novo-ulmi* subsp. *novo-ulmi*, *O. novo-ulmi* subsp. *americana* and *O. himal-ulmi*). Methodology for pathogenicity testing is also summarised in the protocol, and other diseases with symptoms similar to DED are described.

While cultural characteristics (particularly colony growth rates at two different temperatures) can be used to distinguish *O. ulmi* and *O. novo-ulmi*, differentiation of the two subspecies of *O. novo-ulmi* can only be done on the basis of PCR, a laboratory fertility test (Brasier, 1981) or pathogenicity testing. A major limitation of pathogenicity testing however is that young (ca. 3-5 year old) susceptible trees are required, and laboratory fertility testing is complex, requiring known reference isolates of both subspecies and mating types. PCR is therefore the preferred methodology for delineation of the two subspecies, with sequencing undertaken for diagnostic confirmation.

Contact SPHD secretariat for the draft NDP (due to be finalised in 2016). Once finalised, the NDP can be sourced from the National Diagnostic Network website within the Biosecurity

6.8 Pathogen risk ratings and potential impacts

While the potential for DED establishment and spread is considered to be medium for the production nursery sector, entry potential and economic impact are classified as low, and overall risk rated as very low (Industry Biosecurity Plan for the Nursery Industry V3). This low overall risk, which contrasts to the high ratings of the Friends of the Elms Inc., largely reflects the fact that susceptible hosts comprise only a very small percentage of overall nursery production in Australia. Given the population of the elm bark beetles in Australia, the spread potential in elms planted in urban environments left largely unmanaged is high. As such, the impact would be high and have an overall high risk rating.

7 Exclusion, pre-introduction strategies and early detection

7.1 Exclusion

The first line of defence against DED is exclusion. Eradicating invasive fungal pathogens once they are in a nursery or urban environment is very difficult to achieve.

The following imported commodities are considered to be of high risk for the introduction of DED:

- Elmwood imported as timber or finished timber products
- Elmwood packaging material used to support, protect or carry imported cargo
- Elm, Zelkova and Planera nursery stock (cuttings, scion wood and tissue culture) and seeds
- Elm flowers (fresh)
- Bark on timber, chips and handicrafts

The Department of Agriculture and Water Resources (DAWR) may require treatment of these commodities or require other conditions to be met prior to approval of their importation. Elm timber or timber products are not permitted to retain bark unless subjected to an approved DAWR treatment, due to the risk of introducing DED spores or bark beetles which may survive under the bark (Lefoe *et al.*, 2001).

As imported nursery stock represents a high risk for the introduction of DED, a post-entry quarantine program (or pre-entry quarantine program in the country of origin) which includes PCR testing of stem tissue for the DED pathogens, traditional culturing and cross-inoculation procedures, has been recommended for DED-resistant elms imported into Australia (Lefoe *et al.*, 2001).

Current DAWR requirements for the import of *Ulmus* spp., *Planera* spp. and *Zelkova* spp. nursery stock into Australia can be found by searching the BICON database (Australian Biosecurity Import Conditions), which can be accessed at <https://bicon.agriculture.gov.au/BiconWeb4.0>.

Detection of elm bark beetles at Australian ports of entry by DAWR inspectors, wharf workers, container depot staff, etc. is also an important strategy in the exclusion of DED.

7.2 Pre-introduction strategies

A range of pre-introduction measures are recommended for implementation by Lefoe *et al.* (2001), with the aim of:

- Reducing the vulnerability of Australia's elm population
- Detecting an incursion as early as possible
- Ensuring that elm owners, arborists, pest controllers, nursery producers, and government agencies are adequately prepared to respond to an incursion by a DED pathogen.

These measures include adopting effective tree health and sanitation programs (e.g. plant stress reduction), developing elm replacement strategies (e.g. use of DED-resistant elm species, tolerant cultivars⁷), restricting elm plantings near ports of entry, recording elm locations, implementing targeted surveys for early detection of an incursion, maintaining and improving our diagnostic capability, raising awareness of elm pests and diseases, and encouraging general surveillance. These aspects are covered in some detail in Lefoe *et al.* (2001), so emphasis in this plan will be placed on aspects relating to production nurseries.

7.3 Surveys for early detection of an incursion

Early detection of a DED incursion is critical if eradication is to be successful. Illegal introduction of plants, scion wood, cuttings or seed into Australia, or the legal importation of host plants that have not been adequately inspected or treated (including internet sales), provides a high risk for the introduction of DED. Frequent (weekly) monitoring of production systems is recommended (refer to BioSecure HACCP guidelines) and staff must be familiar with the symptoms of DED.

Awareness information should be targeted at managers of production nurseries to ensure that they are familiar with the risks of importing illegal planting material. Material should also describe the legal method by which plants can be introduced and educate growers how to identify and inspect for the presence of the vector and disease symptoms.

7.3.1 Monitoring by nursery producers

Systematic, regular and careful inspection of nursery plants and propagated material for signs of pests and disease should be the basis of all monitoring processes. A range of detection methods should be implemented and performed by production nursery managers

⁷ Warren, K. 2000. The return of the elm: the status of elms in the nursery industry in 2000. J. Frank Schmidt & Son Co. <https://www.ces.ncsu.edu/fletcher/programs/nursery/metria/metria11/warren/elm.htm>

or consultants on behalf of the grower/owner. This will assist in minimizing the risk of entry and establishment of DED.

- If it is not feasible to monitor all plants at one time (because the number of plants and area involved are too great), a representative sample of all host plant species should be visually inspected on a weekly basis for all insects and disease symptoms (weekly crop monitoring plan). Different plants should be monitored each week such that all plants are inspected at least once per month, preferably at least twice. Mother stock plants should be monitored for the presence of disease symptoms and elm bark beetles on at least a weekly basis.
- Symptoms consistent with DED (see Section 6.4) should be reported to the Emergency Plant Pest Hotline (1800 084 881).
- The NGIA Nursery Production Farm Management System provides greater detail on crop monitoring, site surveillance and consignment inspections under the BioSecure HACCP program.

7.3.2 Surveillance by regulatory authorities

Biosecurity staff should regularly survey elms in all areas of Australia as part of their regular surveillance. However, sole reliance on this surveillance is probably insufficient. Inspection of mother stock plants in production nurseries or external plantings represents a more strategic, risk based method of conducting surveillance as their progeny will be sent to many regions across Australia. Retail outlets and production nurseries are infrequently monitored as part of regular biosecurity surveillance. Therefore, business owners are largely left responsible for reporting suspect EPPs.

At a minimum, elms in urban environments should be surveyed for DED symptoms at least twice during the growing season each year. It is recommended to survey trees once when trees flush in early summer and once again towards the end of the growing season.

Where the growing area of relevant host plants is small, it may be possible to inspect nearly all plants. In other cases, where large numbers of plants are being grown over vast areas, it may be possible only to inspect 10-20% at any one time. In this situation, different plants should be inspected each time.

The aims of surveillance are to:

- Locate and record elms and *Zelkova* individuals
- Survey all elms and *Zelkova* in designated areas for disease symptoms
- Submit all samples with DED-like symptoms to a designated laboratory
- Monitor elm bark beetle populations

7.3.3 How to survey and sample individual plants for DED

Surveying an individual plant is usually not difficult as the wilting of branches is very evident. This may be more challenging for large trees; binoculars should be used. Wilting is usually accompanied by a brown streaking in the sapwood which is visible once the bark is peeled away. If a transverse cut is made a brown discoloration of the outer annual ring can be seen.

As the fungus cannot be cultured from dead wood, the sample must be taken from living material that has symptoms typical of DED. Leaves are not required.

The sampling procedure for newly diseased stems of an elm with DED-like symptoms is described in Tan (unpublished) and outlined below:

- 1) Prior to sampling, disinfect pole pruner head and secateurs with several sprays of 80% ethanol or 1% bleach ensuring good coverage so that there is no contamination from previous use.
- 2) Select one or more branches in the elm tree crown that have typical wilt symptoms and leaf browning and remove them. For large trees use a cherry picker or similar equipment to reach appropriate sites.
- 3) Select an older portion of the branch that is about 2 to 3 cm in diameter or larger.
- 4) Cut branch samples from the selected branch of about 15 cm in length. Keep samples as clean as possible. Ensure they are not contaminated with soil and do not place samples on soil.
- 5) Remove side twigs and leaves.
- 6) Check these samples for the presence of cambial layer staining under the bark by removing a 2.5 cm long section of bark near each end of the sample. If no staining is apparent retain the sample but also sample other branches that show symptoms. Leave the bark remaining on samples intact. Ensure the branch is not completely dead when sampled – the cambium should still be moist and green even if streaked with brown and the wood should be moist and soft enough to cut easily.
- 7) Collect 5 or 6 such samples per tree for submission to the laboratory. Ensure that the bark has not been removed on the major portion of these samples.
- 8) It is important that the samples do not become too humid. Wrap each sample piece in waxed paper and twist ends to ensure stem ends are covered. If bark beetles are present, collect these into a separate screw-topped container for submission with the branch sample. Place samples into a heavy duty paper bag with the precise collection details. Ensure the bag is taped or tied to securely contain the contents.
- 9) Place bags containing samples in an esky or similar insulated container to keep them cool. Samples should not be allowed to dry out over a weekend. If samples cannot be submitted immediately, they should be kept in a refrigerator.

Treat excess plant material as though it was infected with DED; store securely on-site or dispose of it by approved methods. Record GPS coordinates for the affected tree.

Surveying officers must obtain permission to enter a property before starting a survey. If the property involved is a production nursery the officer should enquire as to what pesticides have been applied recently as this may affect the abundance of the insect vector as well as preclude safe entry. Particular care must be taken when collecting individual specimens, to prevent contamination of samples and to maintain confidence in the sample from collection

to its final result by a diagnostician. Collectors must exercise extreme care in handling specimens to ensure that hands, tools and other collection supplies do not become a source of contamination between samples and particularly between individual sites. Other exotic pests and pathogens may be present if the infestation was via illegal importation of plant material.

Disinfect hands and pruning/cutting equipment used for sampling with appropriate disinfectants before moving to a new site.

Care must also be taken with larger articles such as shoes, clothing and vehicles, to be certain that these do not become a means of contamination or spread of any pathogens that may be present. See BioSecure HACCP for on-farm monitoring, surveillance and inspection procedures and sample collection.

8 Surveillance and quarantine areas following a detection

8.1 Overview of surveillance and summary of logic following a detection

No one recommendation can be made regarding how pest surveillance and eradication will take place following a detection of DED in Australia. A wide variety of factors will influence management decisions, the most important of which is the location of the detection in relation to host plants (i.e. production nurseries, retail outlets, elm trees in gardens, arboreta, Avenues of Honour and lining city streets). An important course of action following the detection of an emergency plant pest (EPP) is to identify businesses and regions that could be associated with the movement of elm trees and other host plant species to new areas, i.e. traceforwards and tracebacks. Such high risk locations include, but are not limited to:

- Production nurseries supplying retail outlets
- Production nurseries supplying elms, *Zelkova* and *Planera* to cities for parks and gardens
- Retail outlets (hardware, garden centres, supermarkets, weekend markets, etc.)
- Residential home gardens, public parks and gardens, street trees
- Businesses selling elm timber as fire wood or for ornamental purposes (e.g. wood turning etc.)

There are no exhaustive lists of production nurseries and retail outlets that could be supplying host plants of DED in Australia. It is therefore recommended that the response team first determine the locations within close proximity of the detection site. Consultation with the NGI state association may assist in the rapid preparation of a list of relevant businesses.

In the case of a positive diagnosis of DED in a production or retail nursery, the following recommendations are suggested.

- No DED host plant stock should be allowed off the infested property except in the process of completing appropriate destruction protocols, i.e. total movement control.

- All non-host plant stock must be treated with an insecticide approved for elm bark beetles and inspected prior to movement off the infested property.
- All elm, Zelkova and Planera stock in the infested nursery should be destroyed.
- No living trees in the family Ulmaceae will be introduced into the quarantine area.
- Owners of the infested nursery and suspect properties or areas will be advised of the properties status and of the need to destroy elm stock and carry out fungicide, insecticide and fumigant applications as appropriate.

Properties or areas where plants and equipment have been shared or had contact with the infested property, as well as properties or areas where there is a risk that DED may be spread to by vectors should be considered to be suspect properties. DED host plants in suspect properties should be surveyed every week during the growing season.

Systematic surveys and sampling form the basis of locating outbreaks of DED, but are equally important in defining pest free areas. Two types of surveys are required (a) for contact premises in Control Areas which surround the outbreak site (b) surveys outside Restricted and Control Areas which check for additional outbreaks and are the basis for future confirmation of pest-free area status. It is recommended that all businesses in Australia selling or purchasing DED host plants monitor the health of their plants on a weekly basis during the growing season and record their results to support area freedom and report suspect symptoms early.

8.2 Proposed strategies

Control options for Dutch elm disease are limited. Both fungicide and insecticide treatments have been found overseas to be expensive and not always effective (Hintz *et al.*, 2016). Section 6.6 details control options currently available overseas. Strategies for eradication or containment will depend primarily on destruction of hosts, establishment of quarantine zones and development of hygiene and management strategies. Knowledge of the biology and methods of dispersal and survival of *Ophiostoma* spp. are used to formulate strategies for eradication or containment. For example the extent of the quarantine zones should, in part, be determined by the distance travelled by the disease vector, elm bark beetles. Also hygiene practices should relate to known methods of transmission of disease.

Overall, control of DED relies on four basic principles (from Lefoe *et al.*, 2001).

- Stopping the multiplication of the fungus on infected elms and removing sources of inoculum.
- Stopping the transmission of the disease by the vector.
- Stopping the transmission of the disease by root grafts.
- Ensuring the disease is not spread by poor hygiene practices.

These principles can be applied by:

- Restricting the spread of the pathogen on hosts, vectors and contaminated equipment through quarantine and movement controls.
- Identifying and eliminating sources of infection by surveys, and the removal, careful disposal and destruction of infected elms and elm timber.
- Application of prophylactic treatments to control the vector (see Section 6.6.1.2).

- Decontamination of residual root and stump material, vehicles, equipment and other materials.
- Root pruning and removal and destruction of high risk adjacent trees.

8.3 Quarantine areas

Quarantine and movement controls are essential to prevent the spread of the DED pathogen during the eradication and active containment phases. The following three categories of risk are identified to provide the basis for quarantine controls.

Infected Premises (IP): premises or locality where DED is confirmed or presumed to exist. Total movement control is imposed.

Contact Premises (CP): premises or locality containing susceptible host plants, which are known to have been in direct or indirect contact with an IP. Total movement control is imposed.

Suspect Premises (SP): premises or locality containing plants which may have been exposed to DED and which will be subjected to quarantine and intense surveillance every week for at least three weeks. After this time the plants will be sprayed with an insecticide, then resurveyed weekly for a further three weeks to confirm disease freedom. Provided there is no evidence of infection the premises then revert to normal status. Suspect premises may also occur if elm bark beetles caught in pheromone traps are found to have DED spores present on their body, as indicated by fungal plates. Such premises should have host plants surveyed for a total of 6 weeks as indicated above.

Two categories of risk are identified to justify quarantine control on an area basis.

Restricted Area (RA): This area will enclose an area where there are suspect infected trees, positively diagnosed infected trees and adjacent trees (trees growing within a zone where root grafting may occur). This will include all IPs, CPs, and SPs. A high level of movement control and surveillance will be imposed to contain the disease and preserve the pest free area status of unaffected elm trees and nursery production areas.

The RA is not determined by drawing a circle of a certain diameter around the quarantine control area. It may assume an irregular shape based on the number of outbreaks and known location of host plants. The boundaries must be modified as new information becomes available. Traceback and traceforward information will be used to define the RA.

Control Area (CA): A control area will be imposed around the restricted area (RA) to include any elm trees. This may involve an avenue of trees, or trees growing in parks and gardens. The purpose of this area is to control movement of elm material and impose vector control strategies. The area should be intensively monitored for the presence of symptoms at no less than three-day intervals. Once the limits of the disease have been confidently defined, the CA boundaries and movement restrictions should be relaxed or removed, where appropriate.

8.3.1 Trace backs and trace forwards

Trace backs and trace forwards are essential for delimiting survey activities following an initial detection. Trace backs attempt to determine the source of the infection whereas trace forwards further define potential spread of and dissemination of the infection. There are many potential sources of trace backs/trace forwards. These are summarised to assist in the investigations to locate potential populations of DED. However, not all of these will be relevant to all scenarios so one must determine the importance of certain lines of investigation on a case by case basis. In any case, trace backs and trace forwards will identify movement linked to IPs, CPs and SPs.

- Trace backs
 - Investigate where the infected material may have been purchased or obtained, this may include (not an exhaustive list):
 - Retail nursery, weekend or road-side market or internet sale
 - Production nursery – trace back to mother stock plants
 - Staff, aborists, visitors (both domestic & international)
 - Legal or illegal importation
 - Items of equipment, machinery and vehicles which have been shared between properties. For example, equipment used by aborists, such as chainsaws and pruning tools, would be an important pathway to consider
 - Root grafts of nearby trees

Trace back plant movements should focus on stock that was received within twelve months of the detection, or longer if deemed necessary.

- Trace forwards
 - Local movement of elm bark beetles to other host plants in residential properties, parks, gardens, and avenues. Emerging beetles fly to nearby elms for feeding, usually within 80m. After maturation feeding, adult beetles can fly up to 10km to find a suitable breeding tree. Pheromone traps may assist in establishing where elm bark beetle populations are most concentrated.
 - Long distance movement of plants via sale of plants:
 - At production nurseries there should be records of where consignments of plants have been sold. Sales of all host plants should be investigated from the last 6 months, or longer if deemed necessary.
 - At retail outlets, markets etc. – this will cause the scope of residential surveillance to be widened substantially.
 - Movement via root grafts.

For both trace forward and trace back plant movements the critical period could be longer than the stated time periods, as symptoms may take longer than this to appear. This period of time should, of course, be modified based on the individual circumstances of the detection. However, an initial period of six months for trace forward and twelve months for trace back is suggested as a suitable compromise between scientific rigour and the practicalities of responding to a detection.

8.3.2 Establishing a quarantine area

The trigger for the establishment of official quarantine action is either the appearance of “classic” symptoms of DED, or consistent positive results from selected diagnostic tests (colony morphology/colony growth rates), which are normally available within 2 weeks. The diagnostic process will continue through to completion of all the tests required (including PCR and sequencing) for confirmation of the identity of the species/subspecies causing DED. This normally takes at least an additional 2 weeks and as soon as these data are available they are conveyed immediately to the State Plant Quarantine Manager, who is responsible for action under State Legislation.

In some instances a decision may be taken to establish interim quarantine protocols on properties. This will reflect the circumstances at the time and the level of perceived risk. Similarly if the outbreak is reported from a production nursery with commitments to interstate trade then interim quarantine can be justified. Initial quarantines around SPs may be implemented prior to final diagnostic results and modified as required after results become available.

Guidelines for implementation of quarantine zones following detection and/or suspect detection of DED:

- Advise the owners of commercial properties, private homes and agencies responsible for parks, public land, of the presence of suspect DED;
- Explain the need for implementation of quarantine action as a risk management measure until more test results are available;
- Explain what will happen in relation to restrictions on movement of host plants, host plant products, equipment and people and consider the need for appropriate signage;
- Provide preliminary counselling, if required, to owners of affected properties;
- Arrange immediate survey by a qualified plant pathologist and quarantine officer(s) to define the extent of plants showing similar symptoms – affected plants should be mapped using GPS systems;
- Organise trace back and trace forward analyses from IP to identify Contact Premises;
- Record and map the Infected Premises and Contact Premises, and commence the process of defining the quarantine area and associated buffer zones;
- Communicate the evolving situation to the CCEPP, peak industry and government;
- Consider and plan locations for the establishment of barrier controls including highways and transportation centres for freight and people;
- Advise the local authorities, police and appropriate road authorities of the intent to establish quarantine zones and barrier controls to restrict movement of host plant material, host plant products and equipment to within the Restricted and Control Areas;
- Establish barrier controls including: road signs and barriers; roster teams and appropriate on-site accommodation; training in methods of communication and interaction with the public;
- Provide secure storage facilities for discarded plants and plant products and regular removal of collected material in secure containers to approved incinerator or burial sites.
- Implement appropriate actions as per PLANTPLAN.

Refer to Section 9.1 for guidelines on the treatment and removal of affected and suspect plants within a quarantine area.

8.4 Surveillance within the quarantine area

Since all elm, Zelkova and Planera stock at IPs will be destroyed, surveillance will only be required after the quarantine is lifted or relaxed in some way. Surveillance during a containment program should be carefully planned and coordinated. Important factors influencing survey strategies include the distribution of elms and season, which will determine the ease of symptom observation and the life stage of the beetle vector.

The duration of surveillance should be modified depending on the exact situation, e.g. age structure of the population, size of host plants, ease of observing DED symptoms and the size of elm bark beetle populations, as indicated by pheromone traps (traps are useful for detecting levels of elm bark beetle populations but not for eradication purposes as the vector is widely established). However, for SPs that are production nurseries, plants should be surveyed at least weekly for at least 6 weeks. Additional surveillance may be beneficial under certain circumstances. For SPs that are urban environments, intense surveillance should be completed for at least 6 weeks during favourable environmental conditions. Less frequent surveys are recommended after this time, particularly during periods of unfavourable environmental conditions for development of disease symptoms. If SPs first occur during unfavourable environmental conditions (e.g. winter) it is recommended to complete an additional round of 6 week intense surveys once weather has warmed (e.g. in spring).

At least one pheromone trap should be placed at each production nursery within an SP during periods that elm bark beetles could be present, i.e. from early spring to autumn. Traps should also be placed in areas with large numbers of elms in CAs. The exact rate may need to be modified with the design of the trap. Trap replacement should occur as required. It is recommended to have at least a subset of elm bark beetles placed into fungal media to determine if they vector DED pathogens. If only a few elm bark beetles are present, test as many as possible.

Every effort must be made to educate managers of parks and gardens, arborists, nurserymen and the general public about symptoms of DED and of the need to report suspect situations immediately.

8.4.1 Decontamination during surveillance

Spores of the DED pathogens, or spore carrying bark beetles, may be spread from affected to unaffected host plants on pruning equipment, arboricultural vehicles and machinery (Lefoe *et al.*, 2001). It is important to minimise the risk of mechanical spread and all surfaces which are likely to have been in contact with diseased tissue should be decontaminated.

Recommended measures include:

- Use of an appropriate disinfectant (e.g. hypochlorite, quaternary ammonium or similar effective products) or heat (e.g. steam and hot water) on equipment, tools, containers

and surfaces which have been in direct contact with diseased and potentially diseased plants or plant parts, or vectors.

- Low pressure washing and disinfection of equipment, machinery and vehicles (refer to Lefoe *et al.*, 2001, Appendix 11, for further detail)
- Washing hands, changing clothing or disposable suits, and removal or disinfection of footwear when moving from affected to unaffected areas.

8.4.2 Communication, awareness, training and operations

- Each state authority will have a known communication strategy for contact with the public, media and industry, listing designated contact officers for information on aspects of the survey. In particular, nursery producers, managers of parks and gardens, private elm owners and arborists, as well as the general public, should be advised (by press, radio, TV, social media and mail drop) of a DED detection and intention to survey.
- Notices for intention to survey should indicate periods of time when the survey will occur and ask residents to make contact to make special arrangements for dogs or other factors.
- A national DED factsheet, specific to production nurseries, is to be prepared and made available (this will be made available in 2016 by the HIA funded project NY15002 - check the NGIA website). The sheet will contain information on the host plants, the symptoms, photographs of symptomatic plants and contact details (telephone, email, website, etc.) for state agricultural officers to answer public queries.
- A national DED surveyor's identification guide, in the form of a pocket-sized reference and electronic format for portable electronic devices, should be made available to survey team members and arborists. The reference should include photographs of symptomatic plants, and text to describe the symptoms, and is designed to be used in determining whether plant samples need to be taken for further testing.

8.4.3 Recording and reporting survey findings

Each state authority will use a reporting system that ensures that sampled trees can be traced properly. Data collected during a preliminary investigation should be used to estimate the potential for spread, the anticipated rate of spread and to identify endangered areas. Information gathered and recorded on the Survey Form should include the following:

- Geographical location using GPS
- Hosts infested at the site including species/variety, age/developmental stage, type of plant material (e.g. potted plant, in-ground).
- Extent and impact of damage and level of pest prevalence.
- How the pest was detected and identified.
- Recent imports of plants or plant products including nursery stock movements.
- History of the pest on the property or in the area.
- Movement of people, products, equipment and conveyances.
- Mechanism of spread within the area, including likely source of inoculum (infected trees, infected propagation material, etc.).

- Condition of infested plants, including age of plant parts affected (spring flush/autumn flush etc.).

8.5 Establishing pest/disease free areas

If DED is endemic in only certain areas, surveys can be used to identify not only RAs and CAs, but also disease free areas. Four important and ongoing components are essential in maintaining pest/disease free areas (from Lefoe *et al.*, 2001):

- Awareness – including illustrated and informative leaflets, road signs and media campaigns targeted at tree managers, nurserymen, councils, the general public and schools
- Survey – use of systematic, nationally agreed inspection protocols to be implemented at critical times when symptoms are most visible
- Movement controls – development of protocols, backed by State legislation, to restrict movement of elm material, equipment, vehicles and other sources of contamination from RAs to unaffected areas. This will require some form of verification authorization that disinfection protocols and appropriate quarantine measures have been applied prior to movement from an RA.
- Documentation – a national system for recording survey data and for certifying movement of plant material and equipment.

8.6 Minimising risk of re-entry/entry and establishment of DED

Growers in pest free areas will need to consider the introduction of additional management measures to minimise the risk of the introduction and establishment of DED. The measures recommended below are intended as a guide and further information should be sought from the State Quarantine and Agriculture Departments:

- Regularly inspect the production nursery.
- Control movement of visitors and contractors, especially those who may have been into quarantine zones.
- Always check the origin of new propagation/planting material before purchase and import onto the property.
- Avoid the introduction of dirty bins onto the property which contain trash from unknown sites.
- Ensure that second hand equipment is thoroughly cleaned before entry onto the property.
- Record the activities which can be used to authenticate/validate the pest free area for trade purposes.
- Consider placement of elm bark beetle pheromone traps in production nurseries and high risk urban areas. Test a subset of beetles trapped to determine if they have DED pathogens present.

9 Quarantine actions and destruction guidelines

This section deals with the specific actions required to contain and eradicate DED, should this be considered feasible. Actions required for the establishment of quarantine zones and surveillance of DED and its vectors are covered in Sections 8 and 10.

The following steps are required to eliminate sources of infection (Lefoe *et al.*, 2001):

- Urgent identification of infected trees and RAs involving rapid diagnosis and surveillance of suspect areas.
- Imposing rigid quarantine to control the movement of elm material, equipment, vehicles and people.
- Prompt insecticidal treatment, if appropriate, of elms in RAs for beetle vector control.
- Destruction and disposal of infected trees (and adjacent trees where necessary) to remove inoculum sources.
- Thorough cleaning and disinfection of all equipment and vehicles, and other material possibly contaminated with the DED pathogen or vector.

9.1 Quarantine actions at infected premises

These guidelines are for operation at production nurseries, retail outlets, public gardens, street plantings, sporting areas, rural properties, and home gardens.

- Owners/managers of IPs are advised as soon as a positive diagnosis for DED has been made.
- A senior quarantine officer in collaboration with Technical Specialists will first visit the property owner to explain the basis for action, to decide which trees are to be destroyed, and to explain what will happen. Note: action is not to proceed if the owner refuses entry. This issue is to be referred to the State Plant Health Manager who will arrange documentation requirements under legislation and the possible need for escort onto the property.
- As soon as practical, the Leader of the Eradication Team and contractor arrange a site inspection to plan the most efficient method of destruction of elm trees and then explain in more detail what will happen.
- Where practical, vehicles not directly involved in tree removal and disposal should not be taken onto affected properties.
- The plants for removal will have previously been marked with fluorescent paint, (includes all host plants to be destroyed within the buffer zone). At production nurseries it is not feasible to mark every plant; marking each block should be sufficient.
- Insecticide sprays are applied across the affected area (consistent with the State Chemical use procedure) as a risk minimisation strategy to reduce spread of inoculum on insects migrating from the property.
- Standardised procedures are proposed by teams of at least 2 and up to 6. All team members will be trained to recognise host plants (demonstration samples) and disease symptoms by using reference guides. Team Leaders will be appointed and trained in methods of tree removal, disposal and site clean-up. The Team Leader is

the spokesperson for the group and the point of contact for property owners and managers.

- Planning of property/site visits is essential to minimise risks of transfer of disease from infested to “clean” properties/sites. Dedicated teams should be used for visiting properties/sites where DED has been confirmed and these should not then visit properties/sites where disease has not been confirmed.

9.1.1 Strategies for nursery situations

Once there has been a positive diagnosis of DED in a nursery, the nursery is designated as an IP and there will be total movement control of host plants imposed. There will also be total movement control of host plants at all contact premises – i.e. properties containing susceptible host plants that have been in direct or indirect contact with infected trees. Properties or areas where plant, equipment and labour have been shared with an IP, or where there is an obvious risk that a DED pathogen may have been spread to neighbouring properties by vectors, are also included in the RA.

As soon as is practical after a positive diagnosis of DED, the Operations Manager or Site Supervisor will determine the most appropriate method for destroying all elm stock in the IP. Explain the situation to the owner of the IP and brief the operational team assigned to the IP on the basis for action, occupational health and safety requirements, owner’s rights and steps to be taken if the owner does not cooperate.

All staff must have identification tags. No living plants in the family Ulmaceae must be introduced into, or be removed from the IP. The owner of the IP should be advised of the property’s status and the need to destroy all elm stock, and to apply appropriate insecticides, fungicides and fumigants. Protocols and reporting procedures for operational teams entering and leaving properties are the same as for other RAs.

SPs are premises where elm stock may have been exposed to a DED pathogen. Initially total movement control is recommended and surveillance completed as per section 7.4. The duration of movement control should be gauged by the exact situation, the level of risk, number of host plants, number of elm bark beetles that could be moving on and off the property and the likely benefit of stopping plants from being moved off the property.

The owner of the SP will be advised of the property’s status and the need for surveillance and sampling to determine the presence/absence of the DED pathogens. The owner will also be advised on the application of insecticides, fungicides and fumigants where required. After the initial surveillance, elm plants may be treated with insecticides, then re-surveyed every three days for a further three weeks to confirm disease freedom. Provided there is no infection the premise can revert to normal status.

The Manager, Operations, Site Supervisor or Survey Team Leader will record all actions on the appropriate form and advise the Operations Centre on recommendations on treatment and surveillance.

9.1.2 General destruction protocols

- No plant material should be removed from the quarantine area unless it is part of the disposal procedure or as part of regulated movement approved by biosecurity organisations, i.e. when plant material is grown in a pest free area, treated appropriately and is certified by a trained biosecurity inspector. At this time there are insufficient registrations or minor use permits to facilitate this process.
- Disposable equipment, infested plant material or growing media/soil should be disposed of by autoclaving, high temperature incineration or deep burial either on-site (away from contact with host roots) or off-site (after containing the equipment/material in a sealed container that allows treatment of the container).
- Any equipment or plant material removed from the site for disposal should be double-bagged.

9.1.3 Destruction protocols for production nurseries and retail outlets

- For production nurseries, host plants in containers and grown in-ground (soil) should be either incinerated on site (preferred option) or transported in secure trucks and buried at an accredited site to a depth of at least 30cm. Prior treatment of the affected area with appropriate protectant sprays is recommended. Containers should be consigned under supervision to an industrial waste site, and buried. Soil from in-ground beds where affected plants were growing should be treated under supervision with steam or a registered fumigant chemical. Production areas should be disinfested and washed under supervision.
- Prior to leaving the IP all vehicles and equipment are washed under low pressure and steam cleaned or treated with a suitable sterilant. This also includes all the property owners' equipment which may be contaminated by the DED pathogen.
- Disposable clothing is removed and placed in autoclavable bags for treatment at the LCC (Local Control Centre).
- Team Leader records action on an appropriate form and advises the SCC (State Coordination Centre)
- Signs are posted to identify the quarantine area and hygiene practices apply.
- Movement of visitors other than quarantine personnel within the affected area is prohibited (home visits permitted).
- Large, in-ground trees that may be on-site should be treated as per Section 9.1.4 (below).

9.1.4 Destruction protocols for elm trees in parks, avenues lining streets and gardens

Prior to removal on an infected tree, the following actions are required (from Lefoe *et al.*, 2001):

- Any elms confirmed as being infected with a DED pathogen must be either removed within 24 hours, or poisoned with a suitable herbicide and removed within 6 days. Note that it may be desirable to delay removal of positively diagnosed infected trees for 4-5 days to demonstrate the presence of root grafting to adjacent trees, particularly in avenue situations. The technique to demonstrate root grafting is to poison the infected tree with an appropriate herbicide applied by axe blazes to the trunk. Four

days after this application, adjacent trees that have root grafts to the infected tree should be identifiable by herbicide symptoms to their foliage. As there is a high probability of transmission of the DED fungus to root grafted adjacent trees, they should also be removed irrespective of the results of DED diagnostic tests. See recommended actions for adjacent trees below in this section.

- If the infected tree is removed during the period of elm beetle emergence (October-April), or shows signs of an elm bark beetle infestation, the application of a suitable insecticide to the canopy of the tree is recommended to control emerging bark beetles. This treatment should only be carried out where it is safe to apply an insecticide to the canopy.
- If felled material is to be fumigated, burned, or buried on-site, then approvals and notifications must be completed prior to felling the infected tree canopy.
- If felled material is to be transported off-site for burial, the Operations Manager should identify the safest and most direct route (i.e. avoiding elm stands where possible).
- All relevant authorities must be notified prior to felling the infected tree, especially if there is a disruption to traffic or services. Local councils may assist with notifications.
- The Operations Manager should check whether a Local Action Plan for DED is available from the local municipality.
- Before an infected tree is removed, an attempt must be made to prevent the movement of the DED fungus to adjacent trees via root grafts. This can be achieved by making a girdling cut into the sapwood at the base of the tree, and severing root grafts between infected trees and adjacent trees.
- Girdling an infected tree prior to its removal must be done in all instances.
- Trenching between infected trees and adjacent trees should be done if possible. The locations of utilities should be determined before trenching is commenced. Utility companies, and possibly police and road traffic authorities, should be notified. The local municipality may assist in the coordination of this action.

Tree removal and disposal protocols (from Lefoe *et al.*, 2001):

- Infected trees and any adjacent trees likely to be root grafted should be felled by qualified tree workers. Crew and equipment should be assembled and supervised by an experienced and qualified arborist. Signage and barriers must be erected as appropriate.
- Elm material must be disposed of quickly to prevent elm bark beetles emerging and infecting healthy elms in the area, and to avoid attracting elm beetles to the newly cut elm material.
- Material from felled infected trees should be either:

- incinerated on site (preferred option, subject to local laws controlling burning of materials in the open),
 - fumigated and transported in a covered load to a land fill site for burial to a depth of at least 30cm,
 - buried on site to a depth of at least 30cm, or
 - chipped on site (to chips less than 25mm), treating chips with an insecticide in a covered truck, then transporting the covered load to a land fill site for burial to a depth of at least 30cm (suitable for canopy material, trunks may be too large to chip). Burial to be supervised by quarantine agency to ensure material is covered by an effective barrier of soil.
- Grind stumps to at least 10cm below ground level (stumps with attached bark can remain an attractive breeding site to elm bark beetles).
 - Fumigate all debris on-site and then transport the treated material to the burial site.
 - Interior of truck, any tools, equipment and clothing to be decontaminated under supervision prior to leaving the burial site.
 - Sites of tree removal are filled in with soil which is then compacted and levelled.
 - Felled, infected elm material must never be used as firewood, as stored firewood remains a source of inoculum that elm bark beetles can further spread the DED pathogens.

Recommended actions for adjacent trees (from Lefoe *et al.*, 2001):

- Adjacent trees are elms within 15m of an infected tree, or elms which show symptoms of herbicide effects when an infected tree is treated with herbicide.
- Adjacent trees are at a high risk of disease transmission via root grafts, as well as via vectors.
- Carefully inspect adjacent trees for DED symptoms.
- Inspect for signs of vascular streaking when the trunks of infected trees are felled. Streaking in the trunk of an infected tree indicates a greater likelihood of DED having spread to the roots, from where root graft transmission may occur.
- Consideration should be given to foliar insecticide applications for the control of elm bark beetle to elms within 80-100m of an infected tree or suspected infected tree.
- Any adjacent infected tree displaying DED symptoms must be considered a suspected infected tree and sampled immediately for laboratory diagnosis. If DED is confirmed, the tree must then be removed according to destruction procedures for infected trees described previously.
- Adjacent trees not displaying DED symptoms should be removed: 1) if vascular streaking is evident in the trunk of an infected tree, due to the high risk of root graft

transmission, 2) if root grafting to the infected tree has been demonstrated, or 3) if adjacent trees are of low value.

- Any adjacent trees not removed must be monitored every three days for DED symptoms throughout the growing season and intensive (i.e. weekly) monitoring should continue at least through the following season. Root grafts should be severed between these adjacent trees and other elms at the site. If DED symptoms occur, samples must be immediately collected for further analysis and confirmation of infection prior to tree removal.

9.2 Owner reimbursement costs

The main objective in providing Owner Reimbursement Costs (ORC) is to provide an incentive for growers to report suspicious pests or pathogens under the basic principle of no one being worse off or better off as a result of reporting a suspected exotic pest incursion. Providing for these ORCs also provides for social justice for growers who, through no fault of their own, are detrimentally affected by a plan to eradicate an Emergency Plant Pest.

If the positive detection of DED in a host requires its removal and destruction then destruction records must be kept by the LCC of the lead agency(s) involved in order to correctly calculate ORC entitlements.

For further details of ORC guidelines and evidence requirements refer to the Plant Health Australia website: www.planthealthaustralia.com.au

10 Surveys and quarantine guidelines for managing elm bark beetle

10.1 Background

One of the major vectors of DED, the smaller European elm bark beetle *S. multistriatus*, has been established in Australia since 1974. Thus the potential for rapid spread of DED in the event of an incursion by bark beetle, as well as root grafts, is high. *S. multistriatus* is the vector of DED in New Zealand. There are many species of bark beetle that feed and breed on elm in Europe, Asia and Northern America. Most of these form galleries under the bark of living or recently damaged or killed trunks. The DED pathogens produce fungal fruiting bodies in these galleries. When adult beetles emerge and disperse to other elms they may carry fungal spores on their bodies. When feeding in the crotches of twigs on healthy elm trees they will transmit fungal spores to the healthy trees. Some 17 species of bark beetle are able to vector DED. It is of concern that they could spread to Australia in diseased elm wood with attached bark. This means that eradication/containment measures may have to consider the management of more than one vector. An effective management plan for DED needs to consider the life cycle, ecology and control of the vector species present (Lefoe et al., 2001).

After adult *S. multistriatus* emerge from the bark they fly to nearby elms, usually within 80m, where they feed on the phloem and xylem tissues in the twig crotches of healthy elm trees. If

the beetles are infective the spores of DED will enter into the vascular tissue via these feeding wounds. After maturation feeding, adult beetles are attracted to suitable breeding sites by volatiles emitted from dead or dying branches of elm trees. Beetles can fly up to 10 km to find a suitable breeding tree. Female beetles penetrate the inner bark and emit a powerful aggregate pheromone which attracts both male and female beetles. After mating the female beetle lays eggs under the bark. A tunnel is excavated parallel to the grain of the wood, in which the eggs are deposited. As the larvae hatch, each bores a tunnel at right angles to the parent tunnel, forming a characteristic fan shape. Pupation occurs in these galleries and this is followed by the emergence of young adults.

10.2 Controlling DED vectors

10.2.1 Cultural control

Managing vector populations depends on a sound knowledge of their biology and ecology. In overseas countries it has been found that a stringent sanitation program to limit the population of the bark beetles is the most effective means of managing DED. This involves the prompt removal of diseased trees or weak and dying branches to reduce breeding sites for the beetles as well as eliminating the source of the DED fungus.

Besides removing potential bark beetle breeding sites in dead and dying branches, tree health is maintained by regular fertilising, watering and avoiding damage to roots and trunks. Other diseases and pests which may cause a decline in tree health are also carefully managed. These include the elm leaf beetle *Pyrrhalta luteola* Muller which can completely defoliate a tree and eventually lead to its demise. An integrated pest management plan for elm leaf beetle includes chemical, biological and physical control measures.

10.2.2 Mechanical control

This involves using pheromone traps or trap trees. With trap trees unwanted or diseased trees are killed with an herbicide. These trees attract bark beetles which then set up breeding colonies. The action of the herbicide causes the bark to dry and this results in the failure of the breeding colony.

Information on commercially available pheromone traps for bark beetles is provided in Appendix 4.

10.2.3 Biological control

Although biological control will possibly reduce bark beetle numbers it is not an option during an incursion but could be considered if a long term management program was being implemented.

10.2.4 Chemical control

Most insecticides used to manage elm bark beetles overseas are not registered for that specific purpose in Australia. These insecticides include pyrethroids (cypermethrin, esfenvalerate, fluvalinate, permethrin), methoxychlor and chlorpyrifos (Lefoe *et al.*, 2001). Should an incursion occur in Australia appropriate permits and emergency-use approvals will

be required from the relevant Commonwealth and State authorities. Insecticides can be applied to feeding sites in twig crotches or to lower stems. The most appropriate timing for the application of broad spectrum insecticides against *S. multistriatus* in Victoria is in spring just before leaf burst (September) and after early summer foliage growth (December). More information on insecticides for bark beetle control is provided in Appendix 3.

10.3 Monitoring vector populations

Lefoe *et al.* (2001) noted that surveys of established bark beetle populations were not considered to be an effective means of detecting an incursion of the DED pathogen due to the logistics involved with isolation of the fungus from the large numbers of beetles that would have to be collected. For this reason, regular survey of elms for symptoms to identify potential infections is the recommended means for the early identification of an incursion.

It may be appropriate, however, to establish traps in areas where elm bark beetles have not been recorded, such as in Tasmania.

It may also be appropriate to place traps amongst elm populations that are close to high risk sites of entry such as ports or imported goods unpacking areas to aid the early detection and eradication of bark beetles other than the established species, *S. multistriatus*. Placement of other high risk areas may also be appropriate within an ongoing surveillance program.

10.3.1 Pheromone traps

Information on sourcing pheromone traps for elm bark beetles is provided in Lefoe *et al.* (2001) (see Appendix 4 of this document for details). As these traps (which are imported) can be stored for up to two years, it is recommended that at least one laboratory (or other suitable site) in Australia is nominated to maintain a supply of pheromone traps in case of emergency.

10.3.2 Additional requirements for post-introduction vector surveys

Following an incursion of a DED pathogen, it may be appropriate to sample bark beetle populations, in conjunction with an increased level of elm surveys, as a means of determining the extent of an outbreak.

Elm bark beetles should be collected from the site of an initial DED outbreak to determine the bark beetle species present. If an elm bark beetle other than *S. multistriatus*, is detected, then a survey program to determine the extent of infestation of the new species will be required.

The response to the detection of a new species of elm bark beetle may require modification of the actions for quarantine zones and other prescribed measures outlined in the contingency plan. Actions for quarantine zones, for example, will subsequently consider the eradication or containment of that new species, and the role of that species as a potential vector of the DED pathogen.

11 Technical debrief and analysis for stand down

The response is considered to be ended when either:

- Eradication has been deemed successful by the lead agency, with agreement by the Consultative Committee on Emergency Plant Pests and the Sub-committee on Domestic Quarantine and Market Access.
- Eradication has been deemed impractical and procedures for long-term management of the disease risk have been implemented.

A final report should be completed by the lead agency and the handling of the incident reviewed.

Eradication will be deemed impractical if, at any stage, the results of the delimiting surveys lead to a decision to move to containment/management.

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Appendix 1: Important nursery industry contacts

It is important to note that the Industry Development Officers (IDOs) change from time to time. Therefore, the current list may become out of date relatively quickly. For this reason, one can always refer to the NGIA website for the latest details for the NGI for each state and territory. In addition, some states may have more than one IDO, the below list are important contacts who may then direct you to the most appropriate person.

Northern Territory Website: http://www.ngia.com.au/Category;jsessionid=57FAB91F4A656937462E3F34A910B531?Action=View&Category_id=266 Michele Shugg Public Officer/NT Farmers Representative Nursery & Garden Industry Northern Territory PO Box 348 Palmerston NT 0831 Ph: 08 8983 3233 Fax: 08 8983 3244 Email: ngint@ntha.com.au	Western Australia Website: http://www.ngia.com.au/Category?Action=View&Category_id=308 Chief Executive Officer Nursery & Garden Industry of WA PO Box 135 Mount Helena WA 6082 Email: reception@ngiwa.com.au
South Australia Website: www.ngisa.com.au Grant Dalwood Development Officer Mob: 0412 692 600 Fax: 08 8372 6833 Ph: 08 8271 1012 Email: gdalwood@ngisa.com.au 505 Fullarton Rd (Gate A) Netherby SA 5062	NSW and ACT Web: www.ngina.com.au Michael Danelon Nursery Industry Development Officer (NIDO) 344-348 Annangrove Road (PO Box 3013) Rouse Hill NSW 2155 Ph: 02 9679 1472 Fax: 02 9679 1655 Mob: 0400 010 049 Email: michael@ngina.com.au
Queensland Website: www.ngiq.asn.au Kerry Battersby Executive Officer PO Box 345 SALISBURY QLD 4107 Ph: 07 3277 7900 Mob: 0419 683 457 Fax: +61 07 3277 7109 Email: nido@ngiq.asn.au	Victoria Website: www.ngiv.com.au David Reid Nursery Industry Development Officer PO Box 2280 Wattletree Road LPO East Malvern Victoria 3145 Ph.: 03 9576 0599 Fax: 03 9576 0431 Email: david@ngiv.com.au
Tasmania Website: http://www.ngia.com.au/Category?Action=View&Category_id=307 Mark Van Der Staay PO Box 3009 Rosny Park Tasmania 7018 Email: president@ngitas.com.au	Australia Website: http://www.ngia.com.au Peter Vaughan Chief Executive Officer, Nursery and Garden Industry Australia Ph: 02 8861 5107 Fax: 02 9659 3449 Mob: 0400739802 Email: peter.vaughan@ngia.com.au

Appendix 2: Resources and facilities – diagnostic service facilities in Australia

The diagnostic facilities below should be contacted prior to sending any samples to ensure the availability of all necessary equipment and reagents to complete the tests required.

Facility	State	Details
Crop Health Services	VIC	AgriBio Specimen Reception Main Loading Dock, 5 Ring Road La Trobe University, Bundoora VIC 3083 Ph: 03 9032 7515; Fax: 03 9032 7064
DPI New South Wales – Elizabeth Macarthur Agricultural Institute	NSW	Woodbridge Road Menangle NSW 2568 PMB 8 Camden NSW 2570 Ph: 02 4640 6327; Fax: 02 4640 6428
SARDI Plant Research Centre – Waite Main Building, Waite Research Precinct	SA	Hartley Grove Urrbrae SA 5064 Ph: 08 8303 9400; Fax: 08 8303 9403
Biosecurity Queensland	QLD	DAF Ecosciences Precinct Dutton Park Q 4102 Ph: 07 3255 4378; Fax: 07 3844 4529
Department of Agriculture and Food, Western Australia (AGWEST) Plant Laboratories	WA	3 Baron-Hay Court South Perth WA 6151 Ph: 08 9368 3721; Fax: 08 9474 2658
Department of Primary Industry and Fisheries	NT	Department of Primary Industry and Fisheries Plant Industries Division BAL building, Berrimah Farm, Makagon Road, Berrimah NT 0828 Ph: 08 8999 2261; Fax: 08 8999 2312

Appendix 3: Pesticides for the control of DED and its vectors⁸

Insecticides for control of elm bark beetle

Based on overseas experience, candidates for these applications include the following groups of insecticides:

Synthetic Pyrethroids

Uses: Control of elm bark beetles on elms.

Notes: Cypermethrin and esfenvalerate are the preferred insecticides for evaluation for vector control. Permits are required for their use at the rates found to be effective for control of the smaller European elm bark beetle overseas.

Rates:

Synthetic pyrethroid insecticides used overseas for the control of elm bark beetles.

Insecticide	Rate (a.i.)	Application	Effectiveness (Pajares and Lanier 1989)
cypermethrin	0.1%	Foliar spray	Most effective
esfenvalerate	0.1%	-	"
fluvalinate	0.1%	-	Also effective
permethrin	0.1%	-	"

Methoxychlor

Uses: Control of elm bark beetles on elms.

Notes: Methoxychlor applied as a foliar spray is commonly used in the Northern Hemisphere for elm bark beetle control.

There are no registered insecticides containing methoxychlor in Australia. A supply and permit for its use may therefore be difficult to obtain, but is possible if supporting evidence is provided of its use, safety and registration overseas. This product is organochlorine, a group of insecticides which has been largely phased out in Australia.

Rates: 1% methoxychlor applied as a foliar spray (Neumann and Minko 1985).

Chlorpyrifos

Uses: Control of elm bark beetles on elms.

Notes: Used for control of elm bark beetle from brood wood and trap trees.

Rates: 0.5% (brood wood only)

⁸ From Lefoe *et al.* (2001)

Timing spray applications against the smaller European elm bark beetle

The most appropriate times for the application of broad spectrum insecticides against the smaller European elm bark beetle in Victoria are just before leaf burst (September) and after early summer foliage growth (December) (Neumann and Minko 1985). Recommendations on the timing of applications in other States are yet to be developed, but may not differ greatly.

Fungicides to prevent or arrest development of *O. ulmi* and *O. novo-ulmi*

IMPORTANT: Must not be used during the eradication phase as fungicides can mask DED symptoms. During eradication all infected trees must be located and removed.

Thiabendazole

Uses: Preventative treatment or a therapeutic treatment of DED infected elms

Notes: Thiabendazole should only be injected into a diseased elm if the infection is in the very early stages (i.e. only 5-10% of the crown showing wilt symptoms) and the treatment must be re-applied every 2-3 years (Gkinis and Stennes 1980). It is probably not effective if large limbs are diseased. The method is most useful for saving valuable elms in areas where an on-going management program is in place.

Thiabendazole injected once every 2-3 years can also prevent infection of an elm with DED. This method is quite expensive and is usually injected into the root flare, which gives a better dispersal of the chemical throughout the crown, and should be done in spring when systemic chemicals are most readily taken up in elms. Injecting only once every 2-3 years minimises as much as possible the damage that repeated injections can cause.

Rates: To be determined based on overseas usage.

Herbicides for control of unwanted elms and for demonstrating root-grafting

Important: Many herbicides, called translocated herbicides, are absorbed by roots or above-ground parts of the plant, and can be circulated in the plant system to distant tissues (Ware 2000). Because elm suckers are produced by the root system of a parent elm, translocated herbicides may harm parent trees as well as suckers. Extreme caution must therefore be exercised when using herbicides to control elm suckers. Another group of herbicides, contact herbicides, kills only those parts the plant to which the chemical is applied. There are no contact herbicides currently registered for the control of unwanted trees however.

A number of herbicides are registered for the removal and/or suppression of unwanted trees, including elm suckers. A current list can be obtained from the Australian Pesticides and Veterinary Medicines Authority (APVMA).

During an eradication or containment program, it may be desirable to apply a translocated herbicide to infected trees, prior to removal of the tree, in order to demonstrate the presence of root-grafting to adjacent trees. Metsulfuron methyl is applied to infected trees in New Zealand for this reason (information provided below). Metsulfuron methyl is not registered for use on unwanted trees in Australia. Other translocated herbicides, such as glyphosate, may provide an alternative.

Metsulfuron methyl

Uses: Poisoning elm trees, and indicating the presence of root grafting to adjacent trees

Notes: Several products available such as Brushoff[®], but none registered for control of elms in Australia.

Rates: Rates and additives needed for effective treatment to be determined.

Appendix 4: Monitoring vector populations⁹

Monitoring vector populations

Currently, surveys of established bark beetle populations are not believed to be an effective means of detecting an incursion of the DED pathogen because of the logistics involved with isolation of the fungus from the large numbers of beetles that would have to be collected. For this reason, regular survey of elms for symptoms to identify potential infections is the recommended means for the early identification of an incursion.

It may be appropriate, however, to establish traps in areas where the smaller European elm bark beetle has not been recorded, such as in Tasmania.

It may also be appropriate to place traps amongst elm populations that are close to ports or imported goods unpacking areas to aid the early detection and eradication of bark beetles other than the established species, *S. multistriatus*.

Pheromone traps

Both sexes of the smaller European elm bark beetle are strongly attracted to the commercially available impure synthetic pheromone Multilure™ (a mixture of 4-methyl-3-heptanol (>99%), crude synthetic multistriatin (90%), and cubeb oil (10% α -cubebene) (Neumann & Minko, 1985). This has allowed the development of pheromone traps for the monitoring of bark beetle populations.

Pheromone traps can be used to indicate the presence or absence of elm bark beetles, population trends, adult emergence and dispersal, determination of spore loads, and can assist in the targeting of resources in heavily infested areas. Trapping does not effectively control bark beetle populations and trapping alone is unlikely to reduce the overall rate of DED infection (Yonker, 1990).

Traps should be set at least 1.3 m and preferably 3 m above ground level (Neumann & Minko 1985, Spencer *et al.* 1991). In New Zealand, traps are placed widely throughout the Auckland metropolitan area and inspected and replaced weekly during the growing season (John Bain, personal communication).

Pheromone traps for the smaller European elm bark beetle are available from:

Dunluce International P/L
PO Box 922
St Ives NSW 2075
Ph: 02 9983 1776

These traps, which are imported, can be stored for up to two years. It is recommended that at least one laboratory (or other suitable site) in Australia is nominated to maintain a supply of pheromone traps in case of emergency.

⁹ From Lefoe *et al.* (2001)

Other potential suppliers of elm bark beetle pheromone traps include:

<http://www.scentry.com/Monitoring.htm>

<http://www.pherotech.com>

<http://www.greatlakesipm.com/>

<http://www.trece.com/>

Additional requirements for post-introduction vector surveys

Following an incursion of a DED pathogen, it may be appropriate to sample bark beetle populations, in conjunction with an increased level of elm surveys, as a means of determining the extent of an outbreak.

Elm bark beetles should be collected from the site of an initial DED outbreak to determine the bark beetle species present. If an elm bark beetle other than the smaller European elm bark beetle, *Scolytus multistriatus*, is detected, then a survey program to determine the extent of infestation of the new species will be required.

The response to the detection of a new species of elm bark beetle will require modification of the actions for quarantine zones initially, and modifications to other prescribed measures outlined in the contingency plan. Actions for quarantine zones, for example, will subsequently consider the eradication or containment of that new species, and the role of that species as a potential vector of the DED pathogen.