Invasive Species Report: *Araucaria heterophylla* (Salisb.) Franco

Prepared by Robert Vennell – University of Auckland 2015

Email for correspondence: rven674@aucklanduni.ac.nz

Classification

Kingdom:	Plantae
Phylum:	Tracheophyta
Class:	Pinopsida
Order:	Pinales
Family:	Araucariaceae
Genus:	Araucaria
Species:	*A. heterophylla*

Synonyms

Araucaria excelsa, Eutassa heterophylla Salisb., *Araucaria excelsa* var. *glauca, Eutacta excelsa* var. *aurea-variegata, Eutacta excelsa* var. *glauca, Eutacta excelsa* var. *monstrosa, Eutacta excelsa* var. *variegata-alba,*

Common Names

Norfolk Pine, Norfolk Island Pine, Star pine, Triangle tree, Christmas tree, Living Christmas tree, Christmas Plant, House Pine

Figure 1: Descriptive features of *A. heterophylla*. Left – adult ornamental in a typical coastal New Zealand setting. Top Centre – Mature tree showing female cones. Top Right – Thin peeling flakes of bark of a mature specimen. Bottom Right – Close up of the green, scale-like foliage. Bottom Centre – Root system of a mature individual in a coastal setting. Photos: Robert Vennell, Kahuroa

Description/Identification

A large conical tree growing 50 – 70m in height with a straight trunk supporting whorls of 4-7 horizontal spreading branches (Figure 1; Earle, 2015). Foliage is dimorphic; adult leaves are dark green, scale-like, 4-5 mm long whereas juvenile leaves are needle-like, light green and up to 1cm long (Farjon, 2010; Earle, 2015). Plants are monoecious, with pollen cones occurring terminally on branches and large female cones occurring terminally on thick branches (Patil et al 2013; Farjon, 2010). Brown-grey bark is smooth in juveniles and rough, dark and peeling in thin flakes in the adults (Seiler et al. 2015; Landcare Research, 2015) often exuding a thick white resin (Farjon, 2010). Often confused with *Araucaria columnaris* (Gardner et al. 2000) which has a narrow column-like crown, whereas *A. heterophylla* has longer branches producing a pyramidal shape (Little & Skolman, 1989). For extensive description information please refer to Farjon (2010).

Global distribution

A. heterophylla is endemic to Norfolk Island (29.03° S, 167.95° E) a small island territory of Australia located approximately 750km north-west of New Zealand. In its native range it is classified as Vulnerable by the IUCN red list (Thomas, 2011) on account of its restricted distribution and threats from invasive species and habitat modification. The plant has an extensive global distribution and is grown as an ornamental in coastal areas of the Caribbean, Brazil, Chile, Peru, United States, Mexico, Spain, Portugal, South Africa, (Patil et al. 2013) Ivory Coast, Egypt, Turkey, Philippines, Hawaii, Australia and New Zealand (Farjon, 2010).

The first introduction of the species to New Zealand is reported to be in 1836, when the botanist John Edgerly brought seedlings back from Norfolk Island (Burstall & Sale, 1986). Seedlings from this collection were planted in the Bay of Islands and various mission stations throughout Northern New Zealand. Some of these first specimens still exist and are registered as trees of national significance (New Zealand Notable Trees Register, 2009a). Norfolk Island pine became a popular amenity and garden tree for settlers and were planted throughout the country (Bullians et al. 2006) as far south as Kaikoura (Gardener et al. 2000). Many of these early plantings have grown well and cases exist of established stands well over 100 years old (New Zealand Notable Trees Register, 2009b).

A. heterophylla has naturalised on Lord Howe Island - a UNESCO world heritage site - where there is concern about its ability to alter the soil chemistry in a way that disadvantages native species and is consequently targeted for eradication (Farjon, 2010). It is reported as naturalised in parts of the Caribbean; Anguilla, Ascension and Bermuda (Farnham, 2006), the Hawaiian Islands (Armstrong, 2010) and the Island of Malta (Mifsud, 2007). *A. heterophylla* was first reported as naturalised in New Zealand in 1959, regenerating from planted trees on Raoul Island (Wright & Metson, 1959). It is now also known to be naturalised on Motukiki Island in the Bay of Islands (Webb et al. 1988) Motuihe Island in the Hauraki Gulf (de Lange & Crowcroft, 1999) and the southern end of Waihi beach (pers comm. Burns, 2015).

Biological Characteristics

Reproduction & Growth

Conifers such as *A. heterophylla* are all wind-pollinated (Owens et al. 1998). In Araucariaceae there is no pollination drop; pollen germinates on the surface of the cone scale and grows a long tube that penetrates the epidermis to access the ovule (Haines et al. 1984). The cones dry out in late January, releasing the seeds from the central cone axis which remains attached to the tree (Haines, 1983). A large papery seed wing causes the seeds to spin, slowing the rate of descent and enhancing wind dispersal (Haines, 1983). Alternatively, the cones may drop and shatter on impact releasing the seeds (West, 1996). The species produces a large seed mass (around 1700g), with large seed crops every 3.5 years on average (Rejmanek & Richardson, 2003).

The seedlings are light demanding and West (1996) observed that many of the seedlings that germinate beneath parent trees do not survive. Germination of seed requires moist soil (Lodgson, 2005) and maximum germinations rates are achieved between temperatures of 20 – 25°C. (Fullaway et al. 1972). The stems are weak and if covered with too much soil are unable to lift and shed the seed capsule (Lodgson, 2005). Seedlings are best grown in acidic soils (pH 5 – 6.5) with a soil range between sandy loam to clay loam (Backyard Gardner, 2015). The minimum length of the juvenile period is 15 years Rejmanek & Richardson (2003). Growth rate is on average between 0.75 – 1.5m per year and adult trees can reach up to 20 – 40m height (Wilkinson et al. 2000).

Habitats Occupied

A. heterophylla can occur at elevations of 0 – 2000m in humid (>1000mm rainfall >20°C mean temp), sub-humid (>500mm rainfall >20°C mean temp) and coastal zones (Wilkinson et al. 2000). Lower temperature limit was estimated to be between -5.5 and -7.5°C although this was higher (-2.5°C) if plants were not winter-hardened (Offord, 2011). High temperature limit was estimated between 50.5 – 53.5°C (Offord, 2011). The species is salt tolerant and drought tolerant up to 3 – 4 months (Wilkinson et al. 2000), but requires a reliable water source when young (Patil et al. 2013). On its native Norfolk Island, deaths of mature trees can occur as a result of competition with weed species for moisture in times of low rainfall (Director of National Parks, 2010). The species is well adapted to coastal environments as it can grow well in sand (Patil et al. 2013) and has various adaptations to exclude salt. The roots actively exclude NaCl and can be grown in up to 80% sea water (Truman & Lambert, 1978) and the leaves exclude salt from sea spray with a thick, waxy cuticle and a fibrous covering over the stomata (Grieve & Pitman, 1978).

In its original habitat on Norfolk Island, *A. heterophylla* existed as a large (30m+) emergent tree growing above a canopy (10-20m) of evergreen subtropical angiosperms and tree ferns (Benson, 1980). Prior to European settlement it was particularly abundant in the lower levels and slopes (Director of National Parks, 2010). For extensive descriptions of the vegetation communities of Norfolk Island refer to Director of National Parks (2010).

Hosts/Associated Species

The fungal pathogen *Phellinus noxius* causes root and butt rot of Norfolk pines on Norfolk Island and is responsible for dieback of pines (Tiernery, 1987). *P. noxius* is native to Norfolk Island and may have played an important role in causing small disturbances for gap regeneration in native forests (Tierney, 1987). The seeds are a major food source for the native Norfolk Island green parrot (*Cyanoramphus cookii*), and now also serve as a food source for introduced rat species (Earle, 2015). There are observations that they may provide a food source to introduced rodents in New Zealand as well (Waller, 1992; West, 1996).

Competitive Ability

A. heterophylla has a suite of adaptations that allow a strong competitive advantage in coastal environments, such as salt tolerance, mild drought tolerance, and the ability to be grown in sand (Bullians et al. 2006). It is likely that *A. heterophylla* also has impacts on the surrounding soil chemistry which may reduce the germination or growth of other species (West, 1996; Farjon, 2010). The leaf litter contains a range of phenolic metabolites (Michael et al. 2010) and *A. heterophylla* needles have been shown to inhibit the growth of lettuce seedlings (Fuji et al. 2003).

Potential range

The invasive potential of *A. heterophylla* is predicted to be somewhat limited on account of its biological characteristics. A model for predicting conifer invasiveness was applied to *A. heterophylla* and estimated a very low likelihood for invasiveness, based its large seed mass, long juvenile period, and long interval between large seed crops (Rejmanek & Richardson, 2003). These characteristics suggest that population growth would be delayed and infrequent, and seeds unlikely to travel far from the parent plant (Rejmanek & Richardson, 2003). A risk assessment for *A. heterophylla* in Hawaii also predicted a low risk for native ecosystems (Daehler, 2005).

Despite this, the species has naturalised and spread where local conditions are favourable, and given enough time may come to occupy large areas of suitable habitat. Those areas with very similar climatic matches to Norfolk Island are likely to be of most risk to invasion and spread. Raoul Island, for instance, occurs at the same latitude as Norfolk Island and has a very similar climate, and there is concern that without management it could come to dominate all available habitat on the island (West, 1996; West, 2002). Similarly, Lord Howe Island is located around 900km SW of Norfolk Island and there is concern about its ability to spread and dominate the island (Farjon, 2010).

It is currently unclear why there is such a patchy distribution of establishment in New Zealand, and what limits the spread of *A. heterophylla* in climatically favourable areas. It has been speculated that seed predation may have an impact on preventing naturalisation (Gardener et al. 2000). There are reports of seedlings being destroyed by stock and rodents (Waller, 1992) and it was suspected that

Kiore (*Rattus exulans*) were keeping the spread of *A. heterophylla* in check on Raoul Island (West, 2002). As a result, predator-free sanctuaries and mainland islands may be focal points for range expansion, particularly those located in historic farm parks with historic *A. heterophylla* specimens to serve as a propagule source.

Typically low temperatures are thought determine the latitudinal limits of woody plants (Larcher, 2005) and there are as yet, no reports further south than Waihi beach. *A. heterophylla* was found to have limited cold tolerance (Offord, 2011) and this may be a key factor determining its lower latitudinal range. Under some climate change scenarios, New Zealand's average temperature could increase by 3.5$^{\circ C}$ above the 1986-2005 average (Hollis, 2014) which could allow areas further south than Waihi to become suitable for establishment.

Impact

Endangered species & Species Diversity

On Raoul Island, the Department of Conservation classified *A. heterophylla* as a Category A weed in their control management plan – specifying the potential for significant impact on the structure and function of native vegetation (West, 1996). This was for two primary reasons. Firstly there was concern that emergent *A. heterophylla* could overtop *Metrosideros kermadecensis (*At Risk – Naturally Uncommon; de Lange et al. (2012)), and colonise areas of its coastal habitat – potentially changing the structure and composition of the forest. Secondly, there was concern that their ability to create acidic soils would exclude native species from co-occurring in the same area. The species is also targeted for eradication on Lord Howe Island because of concern that it could change the soil chemistry to inhibit native seedling germination (Farjon, 2010).

Human health & Recreation

Although Norfolk Pines are often planted for their aesthetic and cultural value, they can also negatively impact on these values, particularly in the urban environment. Falling branches can be hazardous, particularly in hurricanes and lightning storms (Fontana, 1981), and some coastal communities have banned their planting as a result (Riverwind, 2011). Some people have also reported strong allergic reactions from the leaves and pollen (Patil et al. 2013) and the leaves are toxic to dogs and cats (ASPCA, 2015). In New Zealand there are reports of roots causing structural damage to houses and infrastructure and leaf litter blocking gutters (Newbegin, 2012; Anita Palacio, 2014;). Dieback of pines is a common occurrence in which the pines develop a necrosis and lose their branches (Bullians et al. 2006), which may ruin the aesthetic of the trees and surrounding areas. Greater Wellington Regional Council urges residents against planting Norfolk pine as they believe it will dominate the landscape and spoil the natural beauty of the area (Greater Wellington Regional

Council, 2002).

Ecosystem processes

It is unclear what the effect of *A. heterophylla* would be on native ecosystem processes. Decomposition and nutrient cycling may be altered by the acidic leaf litter, inhibiting the growth of nearby plants (e.g. Wyse & Burns, 2013); however further research would be needed to verify this.

Invasive species

The seeds are a major food source for introduced rat species in its native range (Earle, 2015) and there are reports of rats feeding on seeds in New Zealand as well (Waller, 1992; West 1996; West 2002). Anecdotal reports from Waller (1992) show increased rat abundance during mast years. If this is the case, it may help to facilitate invasive rat populations in New Zealand and could cause negative downstream impacts on native flora and fauna. Further research would be needed to establish whether there is a significant impact on rat populations in New Zealand.

Control technologies

Management of the species on Raoul Island by the Department of Conservation provides a good guide for practitioners elsewhere (see West 1996; 2002). Plants were first separated into those with historic significance and those without. This was done by measuring DBH, and using this as a rough guide to calculate age of the specimens. Once the historic plants had been identified, all other plants were designated weeds requiring eradication. Efforts were focussed in the vicinity of large historic trees as the major propagule source for invasion. Seedlings could be easily pulled out by hand and larger trees cut down with chainsaw (West, 1996). Herbicide is not necessary as the cut stumps do not resprout.

While control of this species is relatively straight forward, the real challenge may come in balancing competing interests to conserve cultural and natural values. On Raoul Island, because it was decided that historic trees planted by settlers were to be preserved, ongoing monitoring and removal of seedlings is required (West, 2002). Conservation programmes which contain historically significant *A. heterophylla* trees should weigh up the potential impacts and ongoing cost of control against the cultural value of preserving the plant *in situ* (West, 2002).

Knowledge Gaps & Research Recommendations

Factors associated with establishment

Knowledge gap: One of the most significant knowledge gaps in assessing *A. heterophylla* invasiveness are the factors associated with its establishment in the New Zealand environment. There is a patchy distribution of establishment across several isolated sites, and it is unclear what is preventing establishment elsewhere. Climatic similarity to the native range is likely a major factor in determining establishment, particularly in areas such as Raoul Island which are located at the same latitude. However, *A. heterophylla* has fairly broad environmental tolerances which extend outside of its native climatic range, and other factors may have an important influence in determining local establishment. While there is speculation about which factors may be important (e.g. Seed predation, soil temperature, soil moisture) there is currently no empirical evidence to determine why *A. heterophylla* has established in some areas and not others.

Research Recommendations: Research should address the disjunct distribution of established populations of *A. heterophylla* in New Zealand. An updated assessment of establishment records would be incredibly useful in approaching this topic. The Waihi site, first reported here, was learned through personal communication and is not available in the literature. Therefore it is possible that other records of establishment exist but have not been formally recorded. Climatic modelling of *A. heterophylla* environmental tolerances (see: Offord, 2011) would be a crucial first step in understanding the large scale predicted range throughout New Zealand. On a local scale, comparisons of habitats where *A. heterophylla* has and has not established would be useful in determining whether there are any factors unique to the sites of establishment that were absent elsewhere. Potentially relevant biotic and abiotic factors from each of the establishment sites (e.g. pH, soil moisture, presence of seed predators) could be compared against sites with planted *A. heterophylla* present but no establishment.

Effects on soil ecosystems

Knowledge Gap: One of the most significant potential impacts of *A. heterophylla* is its effect on the soil environment and growth of native plants. While there is reason to believe that *A. heterophylla* may have allelopathic effects on vegetation and soil organisms (Michael et al. 2010; Fuji et al. 2003) there is a lack of information regarding the practical implications for native vegetation in New Zealand. *A. heterophylla* has been targeted for control on both Lord Howe and Raoul Island in part because of concern over potential changes to the soil conditions (Farjon 2010; West, 1996) but it remains to be demonstrated whether these changes are ecologically significant and warrant management action.

Research Recommendations: Research is needed to establish whether there are any allelopathic effects of *A. heterophylla* on native vegetation and soil communities and whether this is likely to have a significant impact on the structure and function of native ecosystems. Wyse & Burns (2013) tested germination of native seedlings in the presence of *Agathis australis* leaf litter, and a similar research procedure would be useful for *A. heterophylla* with a particular focus on vulnerable native coastal plants. Studies on the decomposition of *A. heterophylla* leaf litter in the New Zealand environment would help address our limited understanding on this issue and would be informative regarding the potential impact of *A. heterophylla* on ecosystem processes. Research looking into the associated mycorrhizal species may also be of great interest.

Feedbacks and associations with introduced rodents

Knowledge Gap: While there have been anecdotal observations that *A. heterophylla* seed fall is correlated with an increase in rodent abundance (Waller, 1992) there is no formal evidence to support this. If seeding did cause real and significant increases in rodent numbers, there could be negative downstream effects to the local ecosystem.

Research Recommendations: Research should attempt to establish whether there is an increase in measures of rat abundance (e.g. Tracking tunnels) during *A. heterophylla* mast seeding. Direct observation of rat feeding would also be useful in strengthening the correlation, for example recording bite marks on seeds and using remote infrared cameras to capture feeding events. The extent of the increase in abundance, if any, will be useful in evaluating whether an increased investment in pest control during seeding events is warranted.

Justification for inclusion as pest requiring some management

A. heterophylla poses a threat to native vegetation and soil communities, and as a result management of this species will be required in some areas of the country. *A. heterophylla* can compete with native species for habitat and resources and alters the acidity of the soil environment potentially reducing the growth of native species. However, *A. heterophylla* will most probably be a low priority control plant for many areas of the country. The plant has limited invasive potential due to its slow growth and short dispersal, and most species are planted as ornamentals away from areas of intact native habitat. However, in areas with humid or sub-humid climates where the plant co-occurs with vulnerable native plant species a greater priority should be assigned to control. Control of the species is straightforward, with simple manual removal of seedlings and trees concentrated in the area immediately surrounding large parent plants.

Further spread of this species may occur in the future with warmer mean annual temperatures expected. There is speculation that establishment may be enhanced in areas where rat populations are controlled; and therefore increased monitoring may be needed in pest-free reserves and parks that contain mature *A. heterophylla* specimens. Because the tree often has historic and cultural value, managers will need to balance these interests against the cost to native ecosystems. Future research should seek to understand the impact of *A. heterophylla* on native environments to better inform management decisions.

References

Anita Palacio (2014). *LAN-62122 Report on an application for resource consent.* Auckland Council: Auckland.

Armstrong, W. (2010). *The Araucaria Family: Past & Present. Retrieved from http://www.pacifichorticulture.org/articles/the-araucaria-family-past-present/*

ASPCA (2015). *Norfolk Island Pine.* Retrieved from: *https://www.aspca.org/pet-care/animal-poison-control/toxic-and-non-toxic-plants/norfolk-island-pine*

Atkinson, I. A. E. (1997). Problem weeds on New Zealand islands. Science & Technical Pub., Departmentment of Conservation: Wellington.

Backyard Gardner (2005) *Araucaria heterophylla (Norfolk Island Pine).* Retrieved from http://www.backyardgardener.com/plantname/pda_b7de-2.html

Benson, M.L. (1980). Dieback of Norfolk Island pine in its natural environment. *Australian Forestry* 43(4): 245-252.

Bullians, M S., Inglis, C., Hill, C., Ganev, S., Braithwaite, M., Ho, W. (2008). Investigating suspect new diseases as part of the New Zealand biosecurity surveillance and response system: an investigation into top dieback in Norfolk Island pine. *Surveillance for biosecurity: Pre-border to pest management*. New Zealand Plant Protection Society Inc., Hastings. 89-96.

Burns, B. (2015). Pers. Comm. [Email]. Senior lecturer in plant ecology. *University of Auckland.*

Burstall, S. & Sale, E. (1986). *Great Trees of New Zealand.* Reed: Wellington.

Daehler (2012). *Araucaraia heterophylla*. Retrieved from http://www.ctahr.hawaii.edu/forestry/trees/Acacia_Azadirachta.html

de Lange, P. J., Rolfe, J. R., Champion, P. D., Courtney, S. P., Heenan, P. B., Barkla, J. W. & Hitchmough, R. A. (2012). Conservation status of New Zealand indigenous vascular plants, 2012. *Department of Conservation*.

de Lange P. J. SL Crowcroft G. M. (1999). The Vascular Flora of Motuihe Island Recreation Reserve. *Auckland Botanical Society Journal* 54:19-30.

Director of National Parks (2010). *Norfolk Island Region Threatened Species Recovery Plan*. Department of the Environment, Water, Heritage and the Arts, Canberra.

Earle, C. (2015). *Araucaria heterophylla*. Retrieved from http://www.conifers.org/ar/Araucaria_heterophylla.php

Fujii, Y., Parvez, S. S., Parvez, M., Ohmae, Y., & Iida, O. (2003). Screening of 239 medicinal plant species for allelopathic activity using the sandwich method. *Weed Biology and Management*, *3*(4), 233-241.

Fullaway, D., Tagawa, T., Trujillo, E., Davis C. & Pung E. (1972) *Norfolk Island Pine Culture.* University of Hawaii: Hawaii.

Fontana, Emilio. (1981). *Twelve dangerous trees*. Miami Herald, Sec. H-6.

Gardner, R., Hambly, G., & Kneijber, J. (2000). Araucaria heterophylla (Araucariaceae) and its relatives. *Auckland Botanical Society Journal* 55: 83-87.

Greater Wellington Regional Council. (2002) *Wairarapa Coastal Strategy*. Retrieved from http://www.gw.govt.nz/assets/Plans--Publications/Wairarapa-Coastal-Strategy/713_caring_for_our_co_s1349.pd

Grieve, A. M., & Pitman, M. G. (1978). Salinity damage to Norfolk Island pines caused by surfactants. III. Evidence for stomatal penetration as the pathway of salt entry to leaves. *Functional Plant Biology*, *5*(3), 397-413.

Haines, R. J. (1983). Seed development in Araucaria Juss. *Australian journal of botany*, *31*(3), 255-267.

Haines, R. J., Prakash, N., & Nikles, D. G. (1984). Pollination in Araucaria Juss.*Australian journal of botany*, *32*(6), 583-594.

Hollis, M. (2014) *Climate Change IPCC Fifth Assessment Report New Zealand findings*. New Zealand Climate Change Centre.

Howell, C. J., & Sawyer, J. W. (2006). New Zealand naturalised vascular plant checklist. *New Zealand Plant Conservation Network, Wellington*, 60.

Landcare Research (2015). *Flora of New Zealand: Araucaria heterophylla***.** Retrieved from http://www.nzflora.info/factsheet/Taxon/Araucaria_heterophylla.html.

Larcher, W. (2005). Climatic constraints drive the evolution of low temperature resistance in woody plants. *Journal of Agricultural Meteorology* 61: 189–202.

Lodgson, B. (2005). Growing the Norfolk Island Pine. Florida Evergreen Nurseries: Florida.

Little, E. & Skolman, R. (1989). *Common Forest Trees of Hawaii. Agriculture Handbook No. 679*. USDA Forest Service: Washington, DC.

Mifsud, S. (2007). *Norfolk Island Pine.* Retrieved from http://www.maltawildplants.com/ARAU/Araucaria_heterophylla.php

Michael, H. N., Awad, H. M., El-Sayed, N. H., & Paré, P. W. (2010). Chemical and antioxidant investigations: Norfolk pine needles (Araucaria excelsa).*Pharmaceutical biology*, *48*(5), 534-538.

Newbegin, E., & Newbegin. (2012). R. *LX-2135331 Notice of application for resource consent.* Auckland Council: Auckland.

New Zealand Notable Trees Trust (2009a). *NR/0734.* Retrieved from http://register.notabletrees.org.nz/tree/view/734

New Zealand Notable Trees Trust (2009b) *BPR/1068.* Retrieved from http://register.notabletrees.org.nz/tree/view/1068

Offord, C. A. (2011). Pushed to the limit: consequences of climate change for the Araucariaceae: a relictual rain forest family. *Annals of botany*, *108*(2), 347-357.

Owens, J. N., Takaso, T., & Runions, C. J. (1998). Pollination in conifers. *Trends in Plant Science*, *3*(12), 479-485.

Patil, A. R., Darekar, A. B., & Saudagar, R. B. (2013). *Araucaria heterophylla*: the review. *World Journal of Pharmacy and Pharmaceutical Sciences, 3(1) 221 – 232.*

Rejmánek, M., & Richardson, D. M. (1996). What attributes make some plant species more invasive?. *Ecology*, *77*(6), 1655-1661.

Rejmánek, M., & Richardson, D. M. (1999, August). Invasiveness of conifers: extent and possible mechanisms. In *IV International Conifer Conference 615*(pp. 375-380).

Richardson, D. M., & Rejmánek, M. (2004). Conifers as invasive aliens: a global survey and predictive framework. *Diversity and Distributions*, *10*(5-6), 321-331.

Riverwind (2011). *Landscape Guidelines and Suggestions.* Architectual Review Committie: Florida.

Seiler, J., Jensen, E., Niermiera, A. & Peterson, J. (2015). *Norfolk pine Araucariaceae; Araucaria heterophylla.* Retrieved from http://dendro.cnre.vt.edu/dendrology/syllabus/factsheet.cfm?ID=655

Saunders, S. M., Dade, E., & Van Niel, K. (2011). An Urban Forest Effects (UFORE) model study of the integrated effects of vegetation on local air pollution in the Western Suburbs of Perth, WA. In *19th International Congress on Modelling and Simulation*.

Tierney J.W. (1989). *Report on investigation into kurrajong (Wikstroemia australis) decline and Phellinus noxius root rot control on Norfolk Island.* Unpublished report to the Australian National Parks and Wildlife Service.

Thomas, P. (2011). *Araucaria heterophylla*. Retrieved from http://www.iucnredlist.org/details/30497/0

Truman, R., & Lambert, M. J. (1978). Salinity damage to Norfolk Island pines caused by surfactants. I. The nature of the problem and effect of potassium, sodium and chloride concentration on uptake by roots. *Functional Plant Biology*,*5*(3), 377-385.

Varnham, K. (2006). Non-native species in UK Overseas Territories: a review. *Joint Nature Conservation Commitee*, *372*.

Waller, B. (2001). Some observations on the germination of *Araucaria heterophylla* (Norfolk island pine) at South Kaipara head. *Auckland Botanical Society Journal*, 56: 14

Webb C J.; Sykes W. R.; Garnock Jones P. J. (1988). *Flora of New Zealand. Vol. IV.* Christchurch Botany Division 1365 p.

West, C. J. (1996). *Assessment of the weed control programme on Raoul Island, Kermadec Group*. Wellington: Department of Conservation.

West, C. J. (2002). Eradication of alien plants on Raoul Island, Kermadec Islands, New Zealand. *Turning the tide: the eradication of invasive species. Gland, IUCN*, 365-373.

Wilkinson, K. M., Elevitch, C. R., & Thaman, R. R. (2000). Choosing timber species for Pacific Island agroforestry. *Agroforestry Guides for Pacific Islands*,*6*.

Wright, A. O. S. & Metson, A. J. (1959) *Soil Bllreau BIII1*. DSIR 10: 17.

Wyse, S. V., & Burns, B. R. (2013). Effects of Agathis australis (New Zealand kauri) leaf litter on germination and seedling growth differs among plant species. *New Zealand Journal of Ecology*, 178-183.