WILDING CONIFERS IN NEW ZEALAND:

STATUS REPORT

Prepared for the Ministry of Agriculture and Forestry

Victoria A Froude
Pacific Eco-Logic Ltd

ISBN: 978-0-478-40010-6 (online)

December 2011

Abstract

Ten introduced conifer species are responsible for most wilding conifers. While many of these species are not now planted commercially, some (e.g. radiata pine (*Pinus radiata*) and Douglas fir (*Pseudostuga menziesii))* still are. Because some introduced conifer species provide significant economic benefits this can complicate their management in locations where they are environmental weeds. Contorta pine is the most invasive introduced conifer species growing in New Zealand and is now an unwanted organism under the Biosecurity Act.

A large area in the eastern South Island is affected by wilding conifers. In 2007 this was estimated to be approximately 805,000ha. This includes 185,000ha mapped as having a wilding cover and 660,000ha that had received past control but were thought to still have wilding conifers (albeit at low levels). The area affected by wilding conifers in the North Island has not been fully mapped although it is estimated that approximately 300,000 hectares of land are affected by wilding conifers at various densities[1].

Low stature native vegetation /ecosystems are particularly vulnerable to wilding conifers. Douglas fir can establish in native beech forests with an open or thinning canopy. A number of the more invasive wilding conifer species (e.g. contorta pine, mountain pine and Corsican pine) are able to grow at altitudes above the local treeline formed by indigenous forest species. In some cases wilding conifer spread may lead to the local extinction of native plant communities and populations of native plant and animal species. Many of the areas affected and/or vulnerable to wilding conifer spread are ecologically valuable protected lands (mostly managed by the Department of Conservation). Other affected public lands include those managed by LINZ and the Ministry of Defence. Large areas of pastoral lease land are affected by wilding conifers and some former pastoral lease land is also badly affected. Areas managed for extensive pastoral farming based on indigenous tussock grasslands that may have been considerably modified by historical land management, can be highly vulnerable to wilding conifer invasion.

Many of the worst wilding conifer infestations are associated with early/ legacy plantings, often by Crown agencies. Today the cost of removing these and other source populations and the associated wilding spread onto public and private lands can be very high. Leaving these areas sees costs of removal rise, often exponentially. There are also risks of wilding conifer spread from some more recent plantings (e.g. Douglas fir spread from plantations is being observed in some areas).

The predictability and visibility of wilding conifers and the short-lived soil seed-bank means that it is more practical to manage their spread than that of many other pest plants. Prevention is the best management. The next best approach is early control before coning –S*titch-in Time-Saves –Nine.* In most cases it is also necessary to remove the source populations/plantings to remove ongoing re-infestation and prevent further spread. A key component affecting the success of any eradication/control programme is follow-up after initial eradication work. While there have been some significant successes, public agencies have insufficient funding for the effective long-term

[1] South island data from North et al 2007, North Island data from Paul & Ledgard 2011

control of wilding conifers. Crown funding for wilding conifer control is severely constrained and may be further reduced. In several of the more problematic areas multi-agency/ community trusts have been established to improve co-ordination and funding.

Wilding conifers do not respect property boundaries. Effective long-term control often requires a co-ordinated multi-organisation /multi-landowner approach, especially when the conifers in an area are on lands of different tenures. There is currently no national framework across all agencies within which to undertake prioritisation consistently so as to deliver greatest return on collective investment. It is proposed that a non-statutory national wilding conifer strategy be prepared with Ministry of Agriculture and Forestry leading strategy preparation. Strategy implementation would, however, need to be a multi-party responsibility.

Contents

Acknowledgements[2]

I would like to thank the many people contributed information and ideas to this project and made comments on earlier drafts. In particular I would like to thank the following people for their contributions:

Ministry of Agriculture and Forestry: Sherman Smith; Alan Tinnelly; Anna Tyler; John Sanson ; Fleur Mathews; Parnell Trost; Gerard Horgan; Peter Gorman, John Novis

Department of Conservation: Keith Briden; Benno Kappers; Clayson Howell; Helen Braithwaite; Lynne Huggins; Kerry Brown; Nicholas Singers; Peter Raal; Sarah Crump; Susan Timmins; Peter Willemse; David Miller; Eddie Te Kahika;

Other central government agencies: David Morgan (LINZ); Murray Mackenzie (LINZ); John Mangos (Ministry of Defence); Rachel Fyfe (Ministry for the Environment); Shaun Bowler (EECA)

Councils
Briana Pringle, Sue Mavor (Queenstown Lakes District Council); Alan Johnson (Marlborough District Council); David Hewson, Philip Grove, Stephen Hall, Ray Maw, Tamsin Page (Canterbury Regional Council); Richard Bowman (Environment Southland); Rob Phillips (Taranaki Regional Council); Jeff Donaldson (Otago Regional Council); Craig Davey, Malinda Mathewson (Horizons MW); Don McKenzie (Northland Regional Council); John Simmons, Kevin Loe, Peter Russell (Waikato Regional Council); Greg Corbett, John Mather (Bay of Plenty Regional Council)

Landcare Research: Duane Peltzer; Ian Dickie; Larry Burrows; Matt McGlone

Scion: Nick Ledgard (retired); Graham Cocker; Thomas Paul

Forestry sector: Aaron Gunn (Blakely Pacific); Peter Weir (Earnslaw One, NZFOA, Douglas-Fir Owners Association), Mark Dean, Keith Wood, Phil De La Mer (Earnslaw One); Dave Lowry, Sally Strang (Hancock Forest Management); Andrew Karalus (Nelson Forests); Dean Witehira (Timberlands)

Land owners/ managers: Hamish Roxburgh (Federated Farmers); Blake Foster, Elaine Curin (Pukaki Downs); John Aspinall (Mid Dome Trust);

Others
Prof Alan Mark (Otago University); Jen Miller (Royal Forest & Bird protection Society); Cathy Begley (Ngai Tahu); John Fairweather (Lincoln University); Brian Cox (Bioenergy Association of New Zealand); Chris Richmond (Pacific Eco-Logic Ltd)

[2] Cover photograph shows Douglas fir spreading from a plantation forest into tussock grassland. Photosupplied by Lynne Huggins, Department of Conservation Southland

Disclaimer

As specified in the terms of reference and the contract for this project, this report has been prepared using published and unpublished reports and papers, interviews and discussions. Specific locations were not visited and raw data was not collected. While every care has been taken in the preparation of this report, Pacific Eco-Logic is not responsible for decisions taken using the contents of this report.

This report should be cited as

Froude, V.A. 2011. Wilding conifers in New Zealand: Status report. Report prepared for the Ministry of Agriculture and Forestry. Pacific Eco-Logic, Bay of Islands. 206p.

Overview of the report

Context and report scope

The purpose of this extended summary is to provide an overview of the report to help users determine which sections they wish to read in more detail. This report was commissioned by the Ministry of Agriculture and Forestry in late April 2011. The terms of reference were broad, addressing: historical factors; current situation; impacts; legislation and policy (including the impacts of this); management and funding; approaches and tools for wilding conifer control; barriers to effective management/control; risks including likely future spread and implications; effects of the Emissions Trading Scheme, pastoral leases and tenure review, related land use issues; current research and potential opportunities. Further matters included a series of case studies and an assessment of natural ecological changes and vulnerabilities of key at-risk ecosystems to wilding conifers.

The report preparation and review process:

- Provided opportunities for a wide range of stakeholders to contribute their perspectives, ideas and information
- Assembled a large amount of relevant information and identified the main issues and options
- Provided an opportunity for people to confirm or question the accuracy or validity of the information collected and provide additional or alternative information
- Identified topics/issues where there is consensus about the problem and potential solutions
- Identified ways that parties could work together to improve policy and management systems affecting wilding conifer management.

Associated purposes of the report were to: assist the Ministry of Agriculture and Forestry to determine its future role with respect to wilding conifers under the Pest Management: National Plan of Action (PMNPA); and identify opportunities for improving the efficiency and effectiveness of New Zealand wilding conifer management.

This report has been prepared using existing information gathered from a variety of sources including published scientific papers, published and unpublished reports and papers prepared for agencies and organisations, face-to-face and telephone interviews with individuals, and special targeted meetings (including three meetings of the New Zealand Wilding Conifer Management Group.

While a variety of naturalised[3] tree species have adverse environmental impacts the terms of reference for this report restricted its coverage to naturalised conifers. Several matters lead to wilding conifers standing out from many other tree-weed species including: their potentially long distance dispersal; some species being commercially planted; their adverse impacts in a wide range

[3] Naturalised tree species are non-native (introduced) tree species that have established populations in the wild and are able to maintain these populations by reproducing in the wild

of environments; and their role as a *transformer weed* (transforming the environment for many other species).

What are the wilding conifers?

Wilding conifers are the natural regeneration (seedling spread) of introduced conifers[4] (including pines). Naturally regenerated or wilding introduced conifers have established from conifers planted for many different purposes. These purposes include timber and firewood production, as a raw product for industrial processes such as pulp and paper production, soil conservation/slope stabilisation, research, shelter and landscaping. Ten conifer species are responsible for most wildings. While many of these species are not now planted commercially, some (primarily radiata pine (*Pinus radiata*) and Douglas fir (*Pseudostuga menziesii)* still are.

Because some introduced conifer species provide significant economic benefits this can complicate their management in locations where they are pests. Even some wilding conifer stands can potentially provide some economic benefit. In this respect some wilding conifer species are different to most other pest species where the objectives for management are relatively clear even if the practicalities and costs may prevent effective action in many areas.

Contorta pine is the most invasive introduced conifer species growing in New Zealand. It is a native of western North America where it is notable for its ability to grow in a broad range of conditions, the ecological extremes covered by its range, and its pioneering ability to invade sites freshly disturbed by fire or storm events (Agee 1998). For a variety of reasons, including concern about its capacity to spread, commercial and non-commercial (e.g. erosion-control) planting of contorta pine ceased by 1980 (Ledgard 2001a). Contorta pine is an unwanted organism under the Biosecurity Act. There have been a number of control operations to remove areas of wilding spread and the original source populations. For example, control in the Central North Island has involved a range of organisations and methods and in some places has been ongoing for forty years.

Douglas fir is the second most widely planted plantation species in New Zealand. Until relatively recently Douglas fir was not thought to present a significant wilding problem. Today, the natural regeneration and spread of Douglas fir into indigenous grasslands, shrublands, scrub, ultramafic ecosystems, and riparian ecosystems is becoming a matter of concern in some parts of New Zealand. Locations affected include Nelson-Marlborough (e.g. Brown et al. (2010)); Southland (Lynne Huggins, Department of Conservation (pers. comm.)); and parts of the central North Island (Nick Singers, Department of Conservation, pers. comm.). Douglas fir is also found in some areas of beech forest (e.g. Brown et al. (2010)).

Compared to introduced pines, Douglas fir is relatively shade tolerant (Davis et al. 2011). Douglas fir is able to spread into shrublands and regenerating native forests before canopies close (Ledgard 2002). It is able to establish in mature beech forest (especially mountain beech), particularly where

---

[4] [4] Introduced conifers are conifer species that are not native to New Zealand. This contrast with the native conifers,such as kauri , rimu, totara and matai

the beech canopies are more open/have a lower cover and the understory is relatively sparse (Ledgard 2006b; Davis et al. 2011). If Douglas fir seed or seedlings are present when native plant communities are disturbed, then Douglas fir wildings may establish and possibly dominate before the native species are able to form a closed canopy (Ledgard 2006b).

It is thought that a major reason for the observed increase in successful regeneration of Douglas fir in the wild is that there are now higher levels of the mycorrhizal fungi specifically associated with Douglas fir in the environment (Ledgard 2005, 2006b). Douglas fir grown from seed dispersed away from planted areas are now more likely to be inoculated by the correct mycorrhizal fungi in their early years. Figure 1 summarises the relative spreading capacity and age of coning for the introduced conifer species most likely to produce wildings.

Relative spreading vigour from highest to lowest	**Species common name**	**Species scientific name**	**Average age of significant coning (years)**
	Contorta pine (lodgepole pine)	*Pinus contorta*	8
	Scots pine	*Pinus sylvestris*	12
	Mountain pines	*Pinus mugo* subsp. *mugo &* *Pinus mugo* subsp. *uncinata*	8
	Douglas-fir	*Pseudostuga menziesii*	12
	Corsican pine	*Pinus nigra*	13
	European larch	*Larix decidua*	12
	Ponderosa pine	*Pinus ponderosa*	13
	Muricata pine	*Pinus muricata*	12
	Maritime pine	*Pinus pinaster*	10
	Radiata pine	*Pinus radiata*	10

Figure 1: Relative spreading capacity and age of significant coning for the most problematic introduced conifer species (from the perspective of their capacity to spread). Source: (Ledgard & Langer 1999)

The extent of wilding conifers

Several projects have mapped the distribution of wilding conifer species at a national level or for the South Island. The most comprehensive of these projects was a jointly funded LINZ/Ministry of Agriculture and Forestry Sustainable Farming Fund project to determine the extent, density category and age category of planted and wilding conifers in the High Country/South Island.

While the figures for the extent of wilding conifers in the South Island can be confusing the best estimate (North et al. 2007) for the South Island is that in 2007 about 805, 000ha were “affected” by wilding conifers. Of this, approximately 660, 000ha had been subject to control and current densities were too low to map. Another nearly 50,000ha of land had also received some confer control in the last 30 years but conifer density was still sufficiently high to map. Another 145,000ha were mapped as having a wilding conifer cover without significant control.

In the North Island it is estimated that 300,000ha are affected by wilding conifers at various densities. As with the South Island there are large areas that have been subject to control operations over different periods of time.

In New Zealand much of the ongoing wilding conifer spread is several generations removed from the original source plantings. Examples include Crown legacy plantings of the highly spreadable contorta pine for erosion control purposes (e.g. Kaweka Ranges (North Island), Branch/Leatham catchments (Marlborough) and Mid Dome (Southland)) and the planting of a variety of introduced conifer species for research purposes (e.g. Craigeburn and Hanmer Forests (Canterbury)). There are also legacy plantings of contorta pine and other conifer species that have spread from shelterbelts and woodlots on private and pastoral lease lands. Forest plantations are also providing a wilding conifer seed source in some locations (e.g. Richmond Range (Brown et al. 2010) and Southland (Lynne Huggins, pers. comm.)).

Regional councils that include one or more species of introduced conifer in their regional pest management strategy (RPMS) have generally made some assessment of the extent of the wilding conifers within the region. Some of these councils have set up a programme to monitor change in the extent of wilding conifers (and sometimes other attributes such as density, age category and species). A Bay of Plenty Regional Council commissioned assessment of contorta pine extent in a 250,000ha part of the East Taupo, Upper Mohaka, Rangitaiki, and Waipunga catchments found that contorta pine extent had increased between 2000 and 2011. In 2000 Pinus contorta covered 10, 300ha (4%) and by 2011 the extent had increased to 13,600ha (5%) (Wildlands Consultants 2011). In 2011 within an expanded area of 486,000ha 27,400ha (6%) were found to be affected with *Pinus contorta*. As not all parts of this expanded area could be assessed it was thought up to 8% of the area could be affected. . Densities varied from 1 tree/ha to >250 trees per ha. Protected natural areas made up nearly 70% of the land affected by *Pinus contorta*.

A desktop study/interview review can identify specific areas where the problem of wilding conifers is increasing (e.g. Southland, inland Marlborough) and areas where the problem is now largely under control following control efforts (but still requiring ongoing surveillance) (e.g. North Island Central Volcanic Plateau, McKenzie Basin public lands). One example of successful control is the McKenzie Basin where wilding conifers on public land are 95% controlled, and following the removal of a further large original planting area over the 2011/2012 summer, wilding conifer management on all current public lands in the Basin will be in maintenance mode. Monitoring in Canterbury High Country catchments has shown that over a ten year period the extent of wilding conifers in some catchments has reduced following control work (mostly removal of extensive sparse infestations). In other catchments the extent increased.

Because of the patchiness of monitoring data It has not been possible to accurately define overall national trends. It is, however, clear that the wilding conifer problem is increasing in some areas and there have been some changes in the sources of the wildings and species involved. Without timely control of problem plantings, and the associated wilding conifers and their progeny, the area affected by wilding conifers can increase exponentially in a relatively short time, along with the costs of control.

Impacts of wilding conifers

Indigenous ecosystems and species

Wilding conifers grow faster and taller than low-stature indigenous vegetation. Indigenous ecosystems that are at particular risk from wilding conifer invasion include: tussock and other indigenous grasslands, alpine ecosystems, subalpine and dryland scrub and shrublands, frost-flats, wetlands, turf communities, geothermal areas, dunelands, ultramafic/serpentine areas, rockfields and herbfields, riparian areas, coastal margins, bluffs and cliffs.

A number of the more invasive wilding conifer species (e.g. contorta pine, the mountain pines and Corsican pine) are able to grow at altitudes above the local treeline formed by indigenous forest species (often mountain beech in eastern areas). Wilding conifers that grow above the native treeline cannot be replaced by native species as part of natural succession processes.

Once wilding conifers invade low stature communities they shade out many of the native plant species and can change soil characteristics. Where the spread results in dense wilding conifer growth (almost forming monocultures that exclude native species) wetlands and riparian areas can become dry, especially in small catchments. Geothermal and low-stature terrestrial coastal ecosystems (e.g. coastal cliffs, dunelands) can be heavily impacted by wilding conifers.

Disturbances resulting from human settlement have had a profound effect on the indigenous woody flora of the South Island drylands, eliminating many formerly widespread woody species and restricting others to small isolated relicts (McGlone 2001). Indigenous pollinators and seed dispersers for these woody species have also been extensively modified. This means that the re-establishment of many formerly common woody native species is likely to be slow or non-existent. Those woody species that colonise the dryland grasslands today must tolerate droughty conditions, mammalian browsing, occasional fires and they must compete successfully with grasses (Walker et al. 2009b). Few indigenous species have these attributes which are more common amongst introduced species (Wardle 1985). Walker et al. (2009b) expected that dryland secondary woody vegetation would be susceptible to dominance by various woody species such as pines, Douglas fir, sycamore, larch and birch over extended time periods, especially in sites that are drier, have more frequent disturbance, and have no/minimal seed sources for the taller indigenous species.

In some cases wilding conifer spread may lead to the local extinction of native plant communities. Examples of threatened communities include: the naturally stunted native shrubland communities on the Nelson Red Hills ultramafic substrates; and remnant shrubland and grassland communities in the intermontane basins of the South Island high country (Harding 2001). Populations of some indigenous species in the South Island High Country are threatened with extinction because of wilding conifers (Harding 2001).

Special features associated with Douglas fir wilding conifers were discussed under *what are the wilding conifers.*

Douglas fir is still the only common introduced conifer species that is capable of invading canopy gaps in native forests (Ledgard 2006b). This is because of its higher tolerance of shade (Ledgard

2006b; Davis et al. 2011). Douglas fir is able to spread into shrublands and regenerating native forests before canopies close (Ledgard 2002). It is able to establish in mature beech forest (especially mountain beech), particularly where the beech canopies are more open/have a lower cover and the understory is relatively sparse (Ledgard 2006b; Davis et al. 2011). Where the canopy of mountain beech forest has thinned (because of old age or possibly an environmental stressor) that forest is more vulnerable to Douglas fir invasion. In that situation Douglas fir saplings can grow faster than beech (Thomas Paul, unpublished data). Once Douglas fir reaches the canopy it provides an ongoing seed source that could lead to eventual replacement of the mountain beech forest by Douglas fir in that location.

Yeates & Sagar (1998) found that the conversion from native tussock grassland to radiata forest led to a reduction in: soil pH, exchangeable calcium, magnesium, potassium and iron. There were lower levels of microbial biomass for carbon, nitrogen and phosphorus in the mineral soils under radiata pine, compared to tussocks reflecting lower soil organic matter inputs to the mineral soil.
A number of the observed soil fauna differences between radiata pine and tussock grassland were associated with the soil differences.

Pastoral farming and forestry

Wilding conifers are not typically a problem for intensive pastoral farming which is characterised by improved pasture and relatively intensive stocking rates. When stocking is sufficiently intense grazing pressure leads to the death of the young conifer seedlings. As a contrast, extensive pastoral farming is based on indigenous tussock grasslands and other low stature indigenous vegetation which may have been considerably modified by historical land management practices (e.g. repeated fires and heavy grazing) and invasion by introduced plant and animal species. Where there have been repeated fires and/or overgrazing by domestic, stock, rabbits and/or ungulates the resilience of the indigenous grasslands has been reduced. When this happens the grasslands are more vulnerable to woody (e.g. wilding conifers) and herb (e.g. *Hieracium*) weed invasion. While sheep stocking above 0.5 stock units per hectare (Beneke 1962) can provide control of wilding conifers, such rates are often not practical for these grasslands.

Once wilding conifers spread onto extensive or marginal farmland the active control required may be difficult for the landowner/ occupier to justify financially given the marginal worth of the land for grazing. This leads some landowners and occupiers to leave the wilding conifers to spread further including onto lands of other tenures. This spread can affect downwind farms as well as areas of conservation, landscape and sometimes recreational value. While the original source of the wilding conifers may have been on-farm plantings (e.g. woodlots, shelterbelts), the source can also be another landowner including the Crown.

Commercial forestry based on introduced conifers can also be affected by wildings. The current owners of a forest may be required by a regional pest management strategy to remove spreading introduced conifer species (e.g. Karioi Forest in the Central North Island). The risk of wilding conifer spread means that forest owners may require land use consents for planting and may need to reduce the size of the intended planting area or not plant in some areas. There are guidelines available which can help foresters reduce the risk of wilding conifers (e.g. (Ledgard & Langer 1999)).

These guidelines do note that foresters should be prepared to monitor and manage any wilding conifer spread.

Water quantity and associated impacts

In many catchments trees are helpful for reducing: catchment erosion processes, the size of flood flows, and in-stream sedimentation and erosion. They can also be helpful for maintaining or enhancing water quality and aquatic habitats. The effects of trees on water quantity in surface waters are not so appreciated in catchments where there are long-term seasonal soil moisture deficits (e.g. Canterbury foothills, Mackenzie Basin). In these catchments flows can be reduced to levels that adversely affect in-stream aquatic ecosystems and existing direct uses of the water (e.g. water supply, irrigation).

Data from a number of New Zealand catchment studies have shown that where pasture has been replaced by radiata pine forest, there has been a reduction in annual surface water yields of 30-81% (Duncan 1996; Environment Canterbury Regional Council 2011), with the upper end of the range being observed in the dry South Island sites. Different parts of the catchment make different contributions to water flow. Mosley (1999) identified riparian zones, valley bottoms, hillside depressions as the areas of greatest water storage. Trees planted or spreading to these areas would have a disproportionate effect on stream flow because they can maintain high rates of transpiration for longer.

Other impacts

Wilding conifers can adversely affect landscape values, especially where those landscapes characterised by indigenous tussocklands and other low stature indigenous vegetation (e.g. South Island high country, Central North Island Volcanic Plateau). While many are concerned that the character of these areas could change to one dominated by North American plants, there are some people who like the introduced trees. Both the South Island high country and Volcanic Plateau are important for tourism and so large scale changes could adversely affect the industry in these areas. Wilding conifers could affect Maori cultural values in some locations. Fires in mature unmanaged wilding conifer stands are likely to burn hot and could potentially threaten adjoining indigenous ecosystems and even planted forests.

Predicting risks of future spread

Unless introduced conifer spread from planted forests and existing wildings is effectively managed the extent of land affected by wilding conifers will increase. Areas most at risk are vulnerable lands downwind of planted and self-established areas of spread-prone introduced conifers. The most recent work on assessing future spread risk has been by Thomas Paul of Scion using GIS tools to apply a decision support system for assessing the risk of wilding conifers establishing at a site as in Ledgard (2008). While more testing is required to define the probability curves it is possible to determine minimum and maximum risk (Thomas Paul, Scion, pers. comm.). There has been some work to improve the underlying data set being used but more work is needed (including a North

Island data set). Accuracy of assessments could also be improved by refinement of the decision support system used to predict the risk of wilding conifer spread.

Legislation and policy

A number of statutes are relevant in the management of wilding conifers. Key statutes are the Biosecurity Act 1993, Resource Management Act 1991, Climate Change Response Act 2002, Crown Pastoral Lease Act 1998 and Land Act 1948 and statutes administered by the Department of Conservation.

Biosecurity

The Biosecurity Act provides for national and regional pest management strategies. There have been no national pest management strategies for plants. Regional pest management strategies (RPMS) vary considerably, reflecting different patterns of present occurrence, varying potential risk profiles, and different political contexts. In most cases the focus is on contorta pine although Southland also includes mountain pine. Several regional pest management strategies include provisions relating to wilding conifers more generally (e.g. Canterbury and Bay of Plenty Regional Councils).

Most strategies reviewed (excluding Canterbury) have specific rules for contorta pine control and containment. The RPMS for Horizons contains a zero density objective for contorta pine within the Volcanic Plateau Control Area. In its most recent RPMS, Horizons has moved to directly control contorta pine on private rateable land within the Control Area. Other parties (Department of Conservation, New Zealand Defence Force, Karioi Forest and roading authorities) undertake control on lands they manage within the Control Area.

The National Pest Plant Accord (New Zealand Government 2008) is a non-statutory agreement between parties. It identifies specific plants as “unwanted organisms” under the Biosecurity Act, thereby preventing their sale, propagation and distribution. Contorta pine is the only introduced conifer that is an “unwanted organism”.

The Biosecurity Law Reform Bill 2010 has been developed to implement a number of methods included in the Ministry of Agriculture and Forestry pest management national plan of action (Ministry of Agriculture and Forestry 2011) including provisions for national policy and simplifying the process for preparing what will become national pest management plans. Another new provision is that Crown will be bound by the good neighbour rules in regional pest management strategies and plans once those strategies/plans have been aligned with national policy direction.

Resource Management Act

The Act provides a hierarchy of planning instruments with: national policy statements and national environmental standards; mandatory regional policy statements and regional coastal plans and optional regional plans; and mandatory district plans. In the context of wilding conifer management, district plans address matters such as:

- Restricting or prohibiting the planting of species known to have a high spread risk in certain locations
- Addressing potential wilding conifer spread risk, impacts and management as part of the assessment process for relevant resource-consent applications

Consultation and refinement processes are well advanced for a National Environmental Standard (NES) for Plantation Forestry. It is proposed that the wilding tree risk calculator (Appendix 4) be used for determining the activity status for new afforestation. Where scores are between 12 and 16 the activity status is restricted discretionary and where the score is greater than 16 the activity status is prohibited. The wilding tree risk calculator is not used for assessing wilding risk where land is replanted, even if the species changes to one where there is a greater risk of spread.

District plans vary in how they address activities that could affect the distribution and density of wilding conifers. The most comprehensive provisions were found in the Queenstown Lakes District Plan. In this plan, the planting of wilding conifer species most likely to spread (contorta pine, Scot's pine, Douglas fir, European larch, Corsican pine, radiata pine) is prohibited in the Rural Zone. Forestry is a discretionary activity and tree planting is a restricted discretionary activity. There is to be no forestry or planning of exotic tree species above 1070m altitude.

Several district councils prohibit or otherwise restrict the growing of some introduced conifer species in all or parts of the rural environment. Several district plans prohibit the growing of contorta pine. Given contorta pine's status as an unwanted organism under the Biosecurity Act, the growing of it anywhere in New Zealand is prohibited. Some specific district plan provisions include:

- The planting of contorta pine and mountain pine is prohibited in the Mountain Resource Area of Southland District.
- The planting of contorta pine is prohibited in rural Central Otago and the planting of Scots pine and mountain pine is a non-complying activity.

While many council plans contain rules applying to parts/all of the rural environment, Clutha District relies on "encouraging" prospective tree-planters to consider wilding conifer spread.

Climate Change Response Act and Forest Act

There are two carbon-management schemes: the Emissions Trading Scheme (ETS) under the Climate Change Response Act 2002; and the Permanent Forests Sink Initiative (PFSI) under the Forests Act 1949 and the Forests (Permanent Forest Sink) Regulations 2007. The ETS provides for landowners to obtain carbon credits (New Zealand units) for:

- Post-1989 forests: Owners of new indigenous or introduced forests established after 31 December 1989 can apply to earn New Zealand units (NZUs) for increases in carbon stock from 1 January 2008. If the carbon in the forest is diminished then units must be surrendered. Participation is voluntary for post-1989 forest owners and if the forest is not registered the change in carbon stock defaults to the Crown
- Pre-1990 forests: These are forests that were already established as at 1 January 1990 and were in introduced forest species as at 1 January 2008. As long as pre-1990 forests are re-established after harvesting, or natural regeneration occurs, there are no liabilities in respect of carbon. Participation in the ETS is mandatory when more than 2ha is to be deforested in

any 5 year period from 1 January 2008. New Zealand units must be surrendered for deforestation.

Wilding conifers can be found on pre 1990 and post 1989 forest land as defined in the ETS. The tree weed exemption provision has removed a potential liability for landowners/agencies/organisations removing wilding conifers from pre 1990 forest land.

There is no prohibition on landowners registering areas of wilding conifers for carbon credits (NZUs) under the Emissions Trading Scheme, as long as this is not contrary to provisions in Resource Management Act plans or a pest management strategy prepared under the Biosecurity Act. In practice existing Resource Management Act plans and regional pest management strategies are unlikely to have much impact on wilding conifers (except for contorta pine outside of Canterbury). As a consequence most landowners with wilding conifer stands that meet the definition of a post-1989 forest will be able to register those stands to gain carbon credits without any obligation to manage subsequent wilding conifer spread. Even though contorta pine is an unwanted organism under the Biosecurity Act; and it is an offence to breed, knowingly communicate, exhibit, multiply, propagate, release, sell or offer to sell contorta pine; contorta pine can still be registered in the ETS in those locations where the regional pest management strategy does not require its removal.

Where forests are registered for the permanent forest sink initiative under the Forest Act (obtaining credit for carbon sequestration via AAUs), there are no requirements that such registration not be contrary with provisions in Resource Management Act plans and/or regional pest management strategies. It may be possible to exclude some wildling conifers from the PFSI as it could be argued that there may not have been active steps taken to create the eligible forest. Conversely it could be argued that the landowner facilitated natural regeneration by leaving wilding conifers/ not grazing an area. As with the ETS there is no requirement for those gaining AAUs to manage any subsequent wilding conifer spread.

With many landowners unable to afford removing existing wilding conifers, especially if they have been left for some years, registration for carbon credits may be a very attractive option. Once registered, a landowner may find there will be a significant financial penalty to pay to remove a wilding conifer forest. This penalty would be a major disincentive for removal. There is a risk that the effectiveness of community programmes to remove wilding conifers from some areas may be compromised if a number of landowners have registered their wilding conifers under the ETS or the PFSI. At least one property has used funds earned from wilding conifer carbon credits to purchase equipment which has been used to remove dense contorta pine wildings with the intention of progressively replacing all the wildings with other species. Conversely, some landowners who may have been prepared to remove wilding conifers if resources had been available may now register their wilding conifer forest in the ETS or PFSI instead. There are no current requirements for landowners registering wilding conifers for carbon credits to manage those wildings in a way that prevents further spread.

Tenure review and pastoral lease land

As at 31 October 2010 (Parnell Trost, Ministry of Agriculture and Forestry, pers. comm.) substantive proposals had been put to leaseholders of 81 pastoral leases covering a total area of approximately 432,000 hectares. Approximately 209,000 hectares (48%) has been retained in Crown ownership as public conservation land, while223,000 hectares (52%) has become freehold land. Five additional pastoral leases covering 126,000 hectares have been purchased by the Crown with the land becoming public conservation land. Covenants have been created for 8% (24, 795 hectares) of land transferred to freehold tenure. Overall the relatively productive low altitude terraces, fans and basins have been transferred to freehold title, while the colder, steeper higher altitude grasslands have become public conservation land (Parliamentary Commissioner for the Environment 2009).

Tens of thousands of hectares of pastoral lease land is affected by wilding conifers (Parliamentary Commissioner for the Environment 2009) and some former pastoral lease land is also badly affected. Given the scale of the wilding conifers problem, the Parliamentary Commissioner's 2009 report on high country tenure review recommended that sufficient additional funding be sought for a sustained woody weed eradication programme. This recognised that that the costs of wilding conifer control increased exponentially over time if the conifers are not addressed promptly and consistently, and that as eradication is labour intensive it could provide employment opportunities.

Land use and wilding conifers

As land use can change rapidly this means that the risk of wilding conifer establishment at a site can also change rapidly. While sheep browsing at levels greater than 0.5 stock units per hectare can be used as a wilding conifer control tool such levels are not necessarily possible on a consistent basis in many parts of the South Island high country and are not appropriate in protected areas. Intact indigenous tussock grasslands and shrublands are more resistant to wilding conifer invasion than areas that have been degraded by repeated fires and overgrazing (domestic or wild animals). These areas of lower stature vegetation (and mountain beech forest with canopy gaps and/or canopy thinning) are still vulnerable, especially to wilding conifer species with more shade tolerance (e.g. Douglas fir).

While the source of much of the wilding conifer problem is from old agency and private plantings, newer plantings (including those from farm shelterbelts/woodlots and plantation forestry) are causing problems in a number of areas. Many of the areas of greatest vulnerability to wilding conifers are those managed by the Department of Conservation. Such areas may also be highly valuable from an ecological perspective. They may already be affected by wilding conifers sourced from early plantings. Some of these earlier plantings may have been undertaken by the Crown either on land that is now managed by the Department or in some cases now managed by forestry companies. Other sources include private and council plantings.

Douglas fir is being planted over larger areas of the South Island high country for a variety of reasons. This increase is coming about as growers either change species after harvesting or grow Douglas fir in new locations. The risk of Douglas fir wilding spread has increased in recent years and managing the risk of this spread is a challenge requiring co-operation between different parties. One possibility could be an accord, developed between the forestry industry, Local Government New

Zealand (on behalf of councils), Ministry of Agriculture and Forestry, Department of Conservation and LINZ. The purpose of this accord would be to develop protocols for the effective prevention and management of wilding conifers spread from planted forests (of all species). A recent example of such accord is the Clean Streams Accord 2003.

Management and funding

There have been various evaluations of the benefits/priorities of specific wilding conifer policies or control programmes. A “cost-utility” analysis (Stephens 2004) of a range of conservation projects in the Department of Conservation administrative unit of Twizel (South Island) found that the potentially severe impacts of wilding conifers and the large proportion of the area that may be invaded, meant that the most cost-effective project in the area was a comprehensive wilding conifer control project. The project that was underway at the time of the analysis was a much lower level of wilding conifer control (because of funding limitations) which was not particularly cost-effective compared to other conservation projects.

Prevention is the best management. The predictability and visibility of wilding conifers and the short-lived soil seed-bank means that it is more practical to manage their spread than that of many other pest plants.

A variety of methods is used in eradication and control programmes depending on terrain, accessibility, conifer size and density, budget, existing vegetation cover and succession trends following conifer control. A key component affecting the success of any eradication/control programme is follow-up after the initial eradication work. There are a number of examples where sporadic funding has led to inadequate follow-up after initial control and the problem has returned in a few years. A strategy of containment can be the most appropriate approach for large inaccessible plantings of spreading introduced conifers, particularly where there are some boundaries that can be easily defended. There are some large areas that were typically planted for erosion-control purposes in the 1950’s -1980’s which today’s management agencies do not have the funding to remove. In some cases removal may create other land management costs/problems.

Some landowners with dense infestations of relatively mature wilding conifers have considered various options for managing those stands for economic benefit. These options have included management for logs (often not an option with unmanaged stands), firewood, pulpwood, and more recently registration for carbon credits under the Emissions Trading Scheme. Under any of these options landowners could transition to species with lower spread risk. One option that has been investigated but not yet actively pursued is the harvesting and chipping of wilding conifers to provide energy for local users.

The largest central government expenditure on wilding conifer control is by the Department of Conservation. Current overall expenditure is estimated at $3.5 million nationally (Keith Briden, Department of Conservation, pers. comm.). The Ministry of Defence has been controlling wilding contorta pine over 63,000 hectares at Waiouru for 40 years. Current annual expenditure is $900,000. LINZ spent $700,000 on woody weed control in the South Island high country in 2007/2008.

The largest council expenditure on an annual basis is by Canterbury Regional Council ($300,000), followed by Horizons ($125,000) and then Environment Southland. Environment Southland made a large one-off contribution ($300,000) to the Mid-Dome project in 2006. Otago Regional Council is unusual in that while there are extensive areas of wilding conifers within the region, it does not spend any money on direct management activities. Queenstown District Council provides direct funding for wilding conifer control.

Community trusts focusing on wilding conifer control have been formed in several areas. They have typically been established in areas of extensive wilding conifer infestation, usually across lands of a variety of tenures. Councils and Crown agencies are involved in most cases and often provide funding and other support

The Ministry of Agriculture and Forestry uses the following questions/"principles" (derived from s61 of the Biosecurity Act) when considering options for biosecurity funding:

1. Which party is best placed to change their behaviour to reduce the costs of the service or the risks that give rise to the need for the service?
2. Which party is best placed to assess whether the benefits of the service at its current level of provision outweigh the costs and consequently influence the level of service provided?
3. Which party is best placed to determine whether the service at its current provision is being delivered most cost-effectively?

In any application of these questions in the context of wilding conifer management there are two complicating factors: the presence of legacy plantings and the time lag between when the spread occurs and when the impacts are experienced.

In the context of Crown legacy plantings and their progeny there are a number of precedents where the Crown has funded environmental restoration activities needed to remedy problems caused by earlier Crown actions. Examples include: Crown funding for the restoration of Lake Taupo and the Rotorua Lakes, and for re-diverting the Kaituna River back into Maketu Estuary. The principles behind these programmes, and Crown acceptance of an obligation to remedy past environmental damage resulting from its actions, should be further investigated in the context of current and future funding for the management of past Crown plantings of spreading wilding conifers (and their consequential progeny).

Research

There is a variety of current research programmes of relevance to wilding conifer management. Future priorities include: modelling the risk of future-spread of wilding conifers (beyond what has already been done); and evaluating long-term succession processes resulting from different control methods in different environments.

A major priority necessary for the accurate monitoring of change and modelling potential future spread is the development of a clear baseline of current wilding conifer extent and intensity (species and density). It is suggested that a centrally managed spatial database, that allows updates and use of the data by many would provide most flexibility. This could be linked to a proposed national

weeds distribution database (Sherman Smith, Ministry of Agriculture and Forestry, pers. comm.). It is suggested that the requirements for the wilding conifers component of the database would need to be clearly specified by users along with standards for data collection and assessments of the accuracy of particular data sets. The electronic wilding conifer Decision Support System would benefit from some field assessments and refinements so that it is more appropriate for a wider range of situations.

Other useful areas for research include:

- The development of a visualisation tool that can be used to demonstrate visually the impacts of different decisions and management regimes for wilding conifers for an area over time
- An assessment of the potential spread of Douglas fir and the associated impacts
- Evaluation of ecosystem responses following the removal of introduced conifers
- Development and use of sterile conifers.

Barriers to the effective management of wilding conifers

Barriers to effective wilding conifer management primarily relate to funding shortfalls, inadequate capacity, perception issues and strategic/policy/process matters. Funding shortfalls apply to public agencies, land owners and occupiers, and community organisations. These shortfalls limit the ability of all parties to effectively control wilding conifers. Community-based organisations can struggle for funding continuity and with the administrative requirements of funders. Costs of key control tools (e.g. helicopters and fuel) have risen faster than inflation and there is still a lack of proven cost-effective tools for removing dense infestations. Capacity issues include the likely downsizing of the technical capacity in the Department of Conservation and lack of capacity of many affected landowners and land occupiers to effectively manage large infestations of wilding conifers.

Incorrect perceptions can be a major barrier to effective and timely management of problem wilding conifers. For example, when there are no visible tall conifers decision-makers and landowners can perceive that there is no problem and other projects have higher priority. Particularly at risk is funding for early control of wilding conifers spread (“Stitch in Time Saves Nine”) and for follow-up control after the initial major control operations

Policy barriers include: the absence of a national strategy to guide priority setting and facilitate co-ordination; inconsistent local government regulatory regimes; no consistent methodology for measuring and reporting; and government policy disincentives to effective and timely wilding conifer management (e.g. aspects of the Emissions Trading Scheme). Other barriers include: opposition from industry to regulatory provisions such as including commercial species within pest management strategies; and a range of personality, ego and political issues.

Integrated management

Wilding conifers do not respect property boundaries. Effective long-term control often requires a co-ordinated multi-organisation /multi-landowner approach, especially when the conifers in an area are on lands under different tenures. Examples of multi-agency co-ordinated management include:

- The Central North Island Contorta Co-ordinating Group
- Mid Dome Wilding Trees Charitable Trust
- Wakatipu Wilding Conifer Control Group
- Waimakariri Ecological and Landscape Restoration Trust
- Marlborough Sounds Restoration Trust
- New Zealand Wildling Conifer Management Group

A number of people involved with wilding conifer management have expressed a strong desire for national co-ordination via a national strategy (statutory or otherwise) for wilding conifer management. This approach is favoured because a national strategy:

- would raise the profile of the wilding conifer problem;
- assist with obtaining the necessary funding on a regular basis;
- help achieve consistency in approach to wilding conifers in regional pest management strategies, and
- assist with priority setting for wilding conifer management across lands of different tenures.

There are several possible mechanisms for preparing such a strategy depending on the level of statutory backing required, the scope of the strategy and the process to be followed. Potential agencies for leading the preparation of such a strategy seem to be limited. The general consensus of those consulted seems to be that with its lead role for Biosecurity, the Ministry of Agriculture and Forestry would be ideally placed to lead the preparation of such a strategy.

Key recommendations

1. That a non-statutory national strategy be prepared for wilding conifer management. The issues and options provide a framework for the strategy.
   Matters that should be addressed include:
   a. The administration and implementation of the relevant legislation and national policy;
   b. Economic aspects including levels and sources of funding;
   c. Priorities for management on lands of different tenures;
   d. Education, research and monitoring (including standards for assessing and reporting change);
   e. Co-ordination across legislation and between organisations:
   f. The management of Crown/regional council/private legacy plantings and their wilding conifer offspring.

   This strategy could be implemented using a variety of statutory and non-statutory mechanisms.

2. That the Ministry of Agriculture and Forestry be the lead agency for preparing this strategy given its biosecurity functions, including the administration of the Biosecurity Act.

3. That stakeholder involvement in the strategy preparation process be formalised using a stakeholder forum and/or advisory group. The existing New Zealand Wildling Conifer Management Group could provide an appropriate stakeholder forum.

4. In the context of developing and implementing recommendation 1, it is recommended that:
    a. An accord[5] be developed between the forestry industry, Local Government New Zealand (on behalf of councils), Ministry of Agriculture and Forestry, Department of Conservation and LINZ. Arising out of the national strategy it may also be appropriate to develop other accords.

    b. Further work is undertaken to determine the level of funding required to effectively control wilding conifers (in priority areas); how costs should be apportioned between different parties in different situations; and potential sources of additional funding.

    c. Options for funding for the removal of problem Crown legacy plantings and the associated wilding conifer spread be investigated as a matter of good faith and prudent long-term environmental management

    d. Options for redressing competing objectives that may hinder the appropriate and timely removal of wilding conifers on private land be further investigated, including those associated with the Emissions Trading Scheme

    e. National policy direction [6] provide guidance about the scope of "good neighbour rules" in regional pest management plans in respect of plant species whose seed can be transported long distances

    f. National policy direction provides guidance on how regional pest management strategies should treat species that are a resource in one place and a pest in another (e.g. introduced conifer species planted and managed for timber, and red deer farmed for many products; both are controlled in other locations)

    g. Options for providing support for collective community action in respect of wilding conifer management be investigated as proposed in the National Pest Management Plan of Action

    h. Tools be developed for increasing public and decision-maker awareness of the risks and impacts of wilding conifers, management needed and what has already been achieved

[5] The purpose of such an accord could be to develop protocols for the effective prevention and management of wilding conifers spread from planted forests. A recent example of such accord is the Clean Streams Accord 2003 (http://www.mfe.govt.nz/issues/land/rural/dairying-accord-may03.pdf)

[6] Under the Biosecurity Act (as is being provided for under Biosecurity Law Reform 2010 and proposed in the National Pest Management Plan of Action)

1 Introduction

1.1 Report purpose and background

This wilding conifer status report was commissioned by the Ministry of Agriculture and Forestry in late April 2011. The original terms of reference (Appendix 1) were broad addressing historical factors, current state, impacts, legislation and policy, current management, control, barriers to effective management/control, risks including likely future spread and implications, related land use issues, current research and potential opportunities. These terms of reference were expanded during the project. Additional matters included a series of case studies and an assessment of natural ecological changes and vulnerabilities for key at-risk ecosystems. Towards the end of the project an additional report was commissioned. The focus of this second report was to evaluate potential future policy options in the context of *Pest Management: National Plan of Action* (Ministry of Agriculture and Forestry 2011) and the information contained in the current report.

The immediate purposes of the report have been to:

- Bring together information to address the terms of reference
- Seek agreement of the various parties in so much as this is possible to the contents of the report including the recommendations
- Identify the issues (risks and unexploited-opportunities) and options for addressing the issues
- Provide recommendations for future action

The report preparation and review process:

- Provided opportunities for a wide range of stakeholders to contribute their perspectives, ideas and information
- Assembled a large amount of relevant information and identified the main issues and options
- Provided an opportunity for people to confirm or question the accuracy or validity of the information collected and provide additional or alternative information
- Identified topics/issues where there is consensus about the problem and potential solutions
- Identified ways that parties could work together to improve policy and management systems affecting wilding conifer management.

Associated purposes of the report were to: assist the Ministry of Agriculture and Forestry to determine its future role with respect to wilding conifers under the Pest Management: National Plan of Action (PMNPA); and identify opportunities for improving the efficiency and effectiveness of New Zealand wilding conifer management.

A second shorter policy-focused document (Froude 2011b) has also been prepared. This document summarises key components in the current report and evaluates current and potential wilding conifer management in the context of *Pest Management: National Plan of Action* (Ministry of Agriculture and Forestry 2011). While the shorter report summarises parts of this report it also contains some additional (primarily policy-related) content.

The current report follows the completion of a Ministry of Agriculture and Forestry Sustainable Farming Fund (SFF) project on South Island wilding conifers. That project had a research focus. It included bringing together information from a variety of sources to compile GIS maps and a database of wilding conifer extent (as at 2007); developing preliminary models to identify locations at risk from future wilding conifer spread; evaluating control methods; and measuring (early) vegetation succession processes following different types of control in several locations. The South Island Wilding Conifer Management Group was established to provide stakeholder feedback and oversight of the project. Following the completion of the SFF project (mid 2010) the Group decided that it would continue to operate, at least in the meantime. The Group has expanded to become the New Zealand Wilding Conifer Management Group, and the focus changed from primarily research oversight and communication, to wilding conifer management more generally.

Current membership of the New Zealand Wildling Conifer Management Group includes representatives from Ministry of Agriculture and Forestry, Department of Conservation, Land Information New Zealand, Ministry of Defence, relevant regional councils, Queenstown Lakes District Council, Federated Farmers of New Zealand, forestry industry, researchers (especially Scion), Royal Forest and Bird Protection Society, and community trusts. The New Zealand Wildling Conifer Management Group has been involved in the preparation of this report (contributing to the terms of reference, commenting on a discussion paper (Froude 2011a) and drafts of the current report. In addition three meetings (two for one day and one for two days) of the group discussed sections of the report (especially 17 and 18). Many stakeholders and organisations provided feedback on different versions of this report.

1.3 Methodology and scope

This report has been prepared using existing information gathered from a variety of sources including published scientific papers, published and unpublished reports and papers prepared for agencies and organisations, face-to-face and telephone interviews with individuals and special targeted meetings. Legislation, policy, regional pest management strategies, regional plans and district plans statements were primarily accessed on-line. A number of scientific papers and reports were also accessed on line.

A discussion paper was prepared for the May 2011 meeting of the New Zealand Wildling Conifer Management Group. This paper was revised after that meeting and sent out again to the Wilding Conifer Management Group mailing list. Further comments were received. A short questionnaire was prepared and distributed to key people in relevant regional councils and Crown agencies. Responses to those questionnaires were returned by email and discussed by telephone. Not all councils returned a response.

Information on conifer distribution/ extent was obtained using a mixture of on-line sources (especially the Wilding Conifer Management Group website), and maps sent by Department of Conservation staff, information in various reports and responses to the questionnaire. No original data was collected.

Several special purpose meetings addressed issues associated with wilding conifers. These included the following: South Island council biosecurity managers; central North Island council and government department biosecurity managers or their representatives; Environment Canterbury staff (on the Emissions Trading Scheme and the implications for wilding conifer management) and Douglas fir growers in the central North Island.

While a variety of *naturalised*[7] tree species have adverse environmental impacts the terms of reference for this report restricted its coverage to naturalised conifers. Several matters lead to wilding conifers standing out from many other tree-weed species including: their potentially long distance dispersal; some species being commercially planted; their adverse impacts in a wide range of environments; and their role as a *transformer weed* (transforming the environment for many other species).

1.4 Plant pests in New Zealand

New Zealand has approximately 2070 native vascular plant species. In 2005 there were 2436 taxa or 2390 species that were *naturalised* (Howell et al. 2006). Of these naturalised species Howell et al. (2006) list 1780 species as being *fully naturalised*. Fully naturalised species are those that form populations that are self-maintained by seed or vegetative reproduction or occur repeatedly in natural, semi-natural or urban environments (Webb et al. 1988).

Howell (2008) provides a consolidated list of 328 vascular plant species that are "environmental weeds" that have significant adverse ecological effects. This list includes more than 15 introduced conifer species. Ledgard & Langer (1999) identify ten species of conifer as being responsible for most wilding conifer spread.

In 1998 the Department of Conservation identified 575,000 hectares of high-priority protected natural areas as threatened by weed species over the following 5-10 years (Owen 1998). This included more than 260,000 hectares of tussock and alpine areas that were identified as threatened by wilding pines. Other woody species also posed a significant threat to protected grasslands, alpine herbfields and frost flats (including heather (*Calluna vulgaris*), broom and gorse).

Lands administered by other agencies have also been affected by a variety of weed species, including introduced conifers. In the eastern South Island relatively large areas of extensively managed private and leased pastoral land have been affected by a variety of woody and non-woody weed species. These weed species include wilding conifers, hawkweed (*Hieracium* spp), gorse, broom and briar rose. Large blocks of former pastoral lease land (some with weeds including wilding conifers) have been transferred to the Department of Conservation over the last 15 years.

Coastal ecosystems have been highly fragmented and weed invasions are an ongoing threat to coastal cliff, dunelands and supra-tidal areas (Froude 2002). Remnant indigenous forests in lowland and coastal environments near human settlement are highly vulnerable to a range of weed species,

[7] Naturalised tree species are non-native (introduced) tree species that have established populations in the wild and are able to maintain these populations by reproducing in the wild

including some tree species that can germinate and grow up into the canopy (e.g. monkey apple (*Acmena smithii*) in northern areas). The relatively open forests and shrublands of east coast drylands are vulnerable to woody weeds including wilding conifers and sycamore.

1.4 Introduced conifers can be both a resource and a weed

Introduced conifer species have been planted in New Zealand over many years for a variety of purposes, including timber (including firewood) production, as a raw product for industrial processes such as pulp and paper production, soil conservation/slope stabilisation, research, shelter and landscaping. Today plantation forests (primarily conifers) occupy 7% of the New Zealand land area. As at 1 April 2010, the total area stocked with introduced conifers is 1, 738, 000ha (New Zealand Forest Owners Association 2011). This was dominated by radiata pine (1, 556, 000ha) with the second most common species being Douglas fir (110, 000ha). Forestry exports in 2010 totalled $3.872 billion (10.23% of New Zealand's exports) (New Zealand Forest Owners Association 2011). Introduced conifers have also been planted outside of plantations. Examples include farm shelterbelts, soil conservation plantings and landscaping

Naturally regenerated or wilding introduced conifers have established from conifers planted for different purposes. Ten conifer species are responsible for most wildings. While many of these species are not planted commercially some still are.

The introduced conifer species that have been planted in New Zealand can be positioned along a gradient of risk for their capacity to spread beyond the area where they have been planted. This means that certain species are more likely to spread. Contorta pine (*Pinus contorta*) poses the highest risk of spread. Introduced conifer species differ in their tolerance to low light levels and how well they can grow and survive in different types of environment. Different types of land cover show varying vulnerabilities to introduced conifer invasion. In general intensively grazed pasture has a low level of susceptibility to wilding conifer invasion. Natural areas (particularly low stature vegetation) and grassland with very low grazing levels are more susceptible.

Because some introduced conifer species that produce wildings also provide significant economic benefits this can complicate their management in locations where they are pests. Even some wilding conifer stands could potentially provide some economic benefit. In this respect some wilding conifer species are different to many other plant pests where the objectives for management are relatively clear and unambiguous.

2 Wilding conifer attributes

Ledgard & Langer (1999) define "*wildings*" as the natural regeneration (seedling spread) of introduced trees. The term is usually applied to conifers, as they represent most of the major spreading forestry species of concern. To avoid confusion with other potential interpretations the term used today is "*wilding conifers*".

Wilding conifers that grow close to the parent tree (seed source) are described as "*fringe spread*". This usually occurs within 200m of the parent trees and is dense as this is where most seed falls. Plants that grow more than 200m and up to many kilometres from the parent trees are described as "*distant spread*". Outlier or distant spread trees are often scattered as less seed arrives and it does so less frequently. Over time, if there is no control, "*outlier*" trees cone and produce seed. Fringe spread from these "*outlier*" trees will lead to new dense stands and opportunities for further distant spread.

2.3 Species involved and their spread capacity

Ten introduced conifer species are responsible for almost all wilding conifer spread in New Zealand. Figure 1 shows the relative spreading vigour of these species.

Relative spreading vigour from highest to lowest	**Species common name**	**Species scientific name**	**Average age of significant coning (years)#**
	Contorta pine (lodgepole pine)	*Pinus contorta*	8
	Scots pine	*Pinus sylvestris*	12
	Dwarf mountain pine and mountain pine	*Pinus mugo* subsp. *mugo & Pinus mugo* subsp. *uncinata*	8
	Douglas-fir	*Pseudostuga menziesii*	12
	Corsican pine	*Pinus nigra*	13
	European larch	*Larix decidua*	12
	Ponderosa pine	*Pinus ponderosa*	13
	Muricata (Bishop) pine	*Pinus muricata*	12
	Maritime pine	*Pinus pinaster*	10
	Radiata pine	*Pinus radiata*	10

Figure 1: Relative spreading capacity and age of coning for the ten most problematic introduced conifer species (from the perspective of their capacity to spread). Source: (Ledgard & Langer 1999)
Some individuals cone earlier. Recent observations indicate that the average coning age could be getting younger (Nick Ledgard, pers. comm.)

The next sub-sections discuss individual species. Further information on introduced conifers and their interactions with indigenous ecosystems and natural succession processes can be found in sections 4.2.2, 4.3 and 4.4.

2.3.1 Contorta pine

Contorta pine is the most invasive introduced conifer species growing in New Zealand. It is a native of western North America where it is notable for is ability to grow in a broad range of conditions, the ecological extremes covered by its range, and its pioneering ability to invade sites freshly disturbed by fire or storm events (Agee 1998). It was introduced into New Zealand in 1880. All four sub-species (*contorta, bolanderi*, *latifolia* and *murrayana)* have been planted *(*Miller & Ecroyd 1987*),* with the sub-species *contorta* being the most vigorous and associated with the most invasion problems (Ledgard 2001a). By 1960 there was more than 10,000ha of planted pure or mixed stands (Miller & Ecroyd 1987). Planting for commercial and non-commercial (e.g. erosion-control)purposes ceased by 1980. This was primarily because of concern about its potential to spread, although there were other reasons (Ledgard 2001a). Contorta pine spread had been evident in a number of locations before 1980. For example, concerns about contorta pine spread at Molesworth led to the removal of three shelterbelts in 1959, and in 1960 local landowners in the Waihopai Valley complained formally about potential contorta pine spread from proposed erosion-control plantings in the headwaters of the Wye Valley.

Contorta pine is a prolific seeder. While it produces good seed crops in three out of four years in its home range, abundant seed crops are irregular in New Zealand (Miller & Ecroyd 1987). Ledgard (2001a) described how the environment, especially rainfall, influences the age of coning/seed production in contorta pine. At a low rainfall (700mm/yr) and low elevation (50m) site all contorta pine trees had produced cones by age eight, while at a higher elevation (850m) and higher rainfall site (1250mm) only 26% had produced cones by age eight and 80% had produced by age 11 (Ledgard 2001a). While the numbers of cones produced per contorta pine tree of a given age is higher at lower elevations (Ledgard 2001a), contorta pine is able to produce seed at higher elevations than most other conifers (and of course all native tree species). In New Zealand the only other introduced conifer able to produce seed at such high elevations (1200m) is dwarf mountain pine (*P. mugo* subsp*. mugo*) (Ledgard 2001a). Contorta pine seed viability in New Zealand is generally 70-90% (Miller & Ecroyd 1987). Its seed is the lightest of all pine species except one.

The inland subspecies of contorta pine (*latifolia* and *murrayana*) and the coastal subspecies (*bolanderi*) produce mainly serotinous cones that do not readily open on the tree until the tree is felled or strongly heated (by fire) (U S Forest Service 1995). Unopened serotinous cones can persist on trees for many years, and on felled trees cone seed may remain viable for longer than released seed (U S Forest Service 1995). In New Zealand cone serotiny may contribute to the slower spread of the three previously mentioned sub-species by reducing the amount of available seed. Non-serotinous cones open shortly after they ripen in autumn.

Seed dispersal is mainly by wind. While much of the seed falls within about 60m of the parent on flat sites, dispersal distances of several km are common in the South Island (Hunter & Douglas 1984). Distances of up to 40km are possible in very strong winds (Ledgard 2001a, 2009b). If left undisturbed these outlier trees can produce seed within ten years and masses of consequent wildings within 15 years. Periodic heavy seed production can lead to “waves” of fringe spread adjacent to parent trees. These “waves” appear to be further apart time-wise in the drier parts of the South Island than in the moister Central Volcanic Plateau of the North Island (Ledgard 2001a).

Although dependent on the specific site conditions, contorta pine seed generally germinates within 3-4 years (Langer 1993). Contorta pine is more palatable to sheep than other conifers, but is only killed if the stem is completely severed at or below the base of the live needles before seedlings reach two years of age (Crozier & Ledgard 1990).

2.3.2 Mountain pine

Mountain pine reaches higher altitudes than any other conifer, reaching 2400-2700m altitude. There are two subspecies, although some people classify them as distinct species or as varieties (which is a lesser level of distinction than subspecies). Its native range is central and south-east Europe.

The first subspecies is *Pinus mugo* subsp. *mugo*. This is a low stature species with a multi-stemmed growth form. It typically reaches 3-6m but can grow to 10m. This subspecies is able to grow to high altitudes because of its low stature and prostrate form at higher altitudes. It is also able to withstand down-sliding snow and debris because its base lies on the ground and ascending shoots emerge as far away as 10m from its root base (Jorgensen 2010). The second subspecies is *Pinus mugo* subsp. *uncinata*. This is a taller tree up to 20m in height.

Pinus mugo is an invasive species in northern Europe. In Denmark, Norway and Sweden it is a well-established alien in extensively managed areas with poor, sandy or leached soils. *P. mugo* invasion affects approximately half of heath and duneland areas in Denmark as well as inland dunes, outwash plains and marginal hill soil areas (Jorgensen 2010).

In New Zealand mountain pine has invaded subalpine and alpine areas above the native treeline in the southern South Island. It is a pest species in several regional pest management strategies (e.g. Southland) and its planting is prohibited or significantly restricted in all or parts of the area covered by several South Island Resource Management Act district plans.

Mountain pine has a low shade tolerance and in northern Europe single species stands older than 100 years are rarely found except where there are very harsh conditions (soil, wind or salt). In these situations mountain pine can be expected to form a permanent cover for hundreds of years (Jorgensen 2010). Normally stands older than 100 years begin to disintegrate and so there is enough light to allow the regeneration of some mountain pine as well as other (typically deciduous) species.

2.3.3 Scots pine

Scots pine (*Pinus sylvestris*) is a native of Europe and Asia. It longitudinal range extends from Scotland/Ireland/Portugal in the west to eastern Siberia while its latitudinal range extends from the Caucasus Mountains in the south to the Arctic Circle in the north. In the northern part of its natural range it is found from sea level to 1000 metres altitude, whereas in the southern part of its range it is found from 1200-2600m altitude. Scots pine formed much of the original Caledonian Forest in Scotland, although today only about 1% of the original 1.5 million hectares remains (http://en.wikipedia.org/wiki/Scots_Pine)

Scots pine can establish in a wide range of climate and soil conditions, including nutrient-poor soils. Scots pine was primarily introduced to North America for Christmas trees, erosion control and "land reclamation" purposes. There, it is an ecologically invasive species with a moderate impact. In New Zealand most Scots pine was originally planted for erosion control or timber production purposes. For example Scots pine was the main species planted in 240ha in the Tarnsdale area at Molesworth Station (Marlborough). Some blocks of Scots pine at altitudes of around 900m were pruned and thinned in 1990-91 (Ledgard 2004d). In the early 1990s the risk (fast early growth, early seed-production and vigorous spreading) posed by large areas at Scots pine at the Tarndale/ Sedgemere Lakes area was recognised and around 100ha of mature trees and younger regeneration in the most exposed areas were cleared. This was not completed before seed production began and Scots pine spread onto surrounding mountains. At Molesworth Station, Scots pine has been found to cone at altitudes above 1000m and establish from seed at least up to 1200m (Ledgard 2004d).

2.3.4 Douglas fir

Until relatively recently Douglas fir was not thought to present a significant wilding problem (Chevasse 1979). In earlier years severe chlorosis and poor growth of Douglas fir had been frequently reported in New Zealand (Gilmore 1958) as a result of nursery stock lacking appropriate mycorrhizal fungi (Davis 2008). Gilmore found that the problem could be corrected by adding forest duff from a healthy Douglas fir forest into seedling planting holes.

Severe chorosis in Douglas fir seedlings in Edendale Nursery in 1981-82 were found to be caused by a lack of appropriate mycorrhizal fungi (Chu-Chou & Grace 1987). This was corrected by inoculating seedlings with spores from an effective fungal species (*Rhizopogan parksii*). Davis (2008) suggested that new nurseries, those nurseries that had not recently grown Douglas fir and container-grown plants may need to be inoculated with the appropriate ectomycorrhizae. While Davis observed that a lack of mycorrhiza had not been reported to be a problem for pines or other introduced forest species in New Zealand, the failure of *Larix occidentalis* and the poor early growth of *Abies* species in research trials may have been caused by a lack of appropriate mycorrhizal fungi (C. Low pers. comm. cited in Davis 2008).

At Craigeburn the number of Douglas fir seedlings under mountain beech was found to have increased tenfold between 1989 and 2001 (unpublished trials reported in Ledgard (2006b)). In 1989 most seedlings were unhealthy and chlorotic with little growth before either dying after a few years or becoming green and beginning to grow successfully. By 2001 the proportion of green seedlings had increased from virtually none in 1989, to 60%. It was likely that the greening of the seedlings was associated with the roots acquiring the appropriate mycorrhizae (Davis et al. 1996; Davis 2008). It is thought that a major reason for the observed recent increase in successful regeneration of Douglas fir in the wild is that there are now higher levels of the mycorrhizal fungi specifically associated with Douglas fir in the environment (Ledgard 2005, 2006b). Douglas fir grown from seed dispersed away from planted areas are now more likely to be inoculated by the correct mycorrhizal fungi in their early years. Department of Conservation staff in Nelson-Marlborough, Southland and Tongariro-Whanganui-Taranaki conservancies, report increases of Douglas fir natural regeneration in natural areas managed by the Department (Lynne Huggins, Kerry Brown and Nicholas Singers, Department of Conservation pers. comm.).

Compared to the introduced-pine species, Douglas fir is relatively shade tolerant (Davis et al. 2011). Douglas fir is able to spread into shrublands and regenerating native forests before canopies close (Ledgard 2002). It is able to establish in mature beech forest (especially mountain beech), particularly where the beech canopies are more open/have a lower cover and the understory is relatively sparse (Ledgard 2006b; Davis et al. 2011). If Douglas fir seed or seedlings are present when native plant communities are disturbed, then Douglas fir wildings may establish and possibly dominate before the native species are able to form a closed canopy (Ledgard 2006b).

Douglas fir wildings are now invading shrublands and "non-improved" grasslands with increasing frequency (Ledgard 2006b). Such invasion can take place above the treeline formed by native forest species (e.g. near Queenstown). Douglas fir seed production drops off quickly as altitudes exceed 1000 metres (depending on aspect) although seedlings can establish up to 1200 metres (Ledgard 2005).

Douglas fir produces abundant viable seed from about year 15 in New Zealand (Miller & Knowles 1994). Cones can be produced at an earlier age (Ledgard 2002). Good seed crops occur every one to three years in Canterbury (Miller & Knowles 1994). Seed production decreases with altitude, especially above 1000m. Very little coning takes place above 1200m (Ledgard 2006b). The average viability of Douglas fir seed is 75% (Miller & Knowles 1994). Douglas fir has the third lightest seed of the common introduced conifer species found in New Zealand, after contorta pine and Scot's pine (Ledgard 2006b).

As with other conifers, Douglas fir seed is disseminated by wind. Douglas fir cones hang down from branch tips, rather than being held closer to the main stem like other spreading conifers. This appears to assist with seed dissemination. Most seed falls close to the parent tree (Slow (1954) reported within 25m), but this can increase significantly to at least 6km from a wind-exposed take-off site (Cattaneo 2002). A 1986 trial found most Douglas fir seedlings germinate within two-three years and none germinated after five years (Ledgard 2006b). Ledgard (2006b) commented that while it may appear that some seedlings germinate after five years, browsing and a lack of mycorrhiza mean that some plants may remain only a few cm high for several years and may be hidden under other vegetation.

Unpublished trials described in Ledgard (2006b) found that seven years after sowing into different vegetation types, Douglas fir survival was best in shrubland, followed by grassland, then mountain beech forest canopy openings, and worst in intact beech forest. Cattaneo (2002) found that the light and shelter offered by widely spaced plants in open shrublands assisted Douglas fir establishment and that some Douglas fir seedlings were able to establish within shrubs with an average height of 0.5-1m. No contorta pine seedlings were found growing through shrubs.

Even though Douglas fir seedling survival is lower in native (beech) forests than for other vegetation types, Douglas fir is still the only common conifer capable of invading canopy gaps in native forests because of its higher tolerance of shade (Ledgard 2006b). Where the canopy of mountain beech forest has thinned (because of old age or possibly an environmental stressor) that forest is more vulnerable to Douglas fir. In that situation Douglas fir saplings can grow faster than beech (Thomas

Paul, pers. comm.) although it usually takes many decades before Douglas fir to reach and overtop the beech canopy (Nick Ledgard, pers. comm.). Once Douglas fir reaches the canopy it provides an ongoing seed source that could lead to eventual replacement of the mountain beech forest by Douglas fir in that location.

In his review of issues and opportunities for higher altitude introduced conifer forestry in Canterbury, Otago and Southland Ledgard (2005) stated that four species are now being planted in the high country. Ledgard stated that of these four species Douglas fir is planted most widely and has the greatest risk of spreading. Reasons for this included it often being planted in areas where it is surrounded by lightly vegetated and grazed lands; it is a prolific producer of light seed from a relatively young age (12-15 years); cones hang at the end of branches and so the seed can be readily picked up by the wind (c.f. pines); it is more shade-tolerant than pines and can more readily invade shrublands and open forest (Cleary 1982; Klijzing 2002).

2.3.5 Other introduced conifer species

A wide range of introduced conifer species have been planted in the eastern South Island and elsewhere in New Zealand. Of those species most prone to spreading (contorta pine, the mountain pines, Bishop's pine (*P. muricata*), and Scot's pine (Ledgard 2005)), most are rarely planted today. However, as long as trees of these species remain, wilding spread is likely to continue.

In addition to contorta pine, the mountain pines, Scots pine and Douglas fir; Corsican pine is also able to grow at altitudes above the treeline formed by indigenous species. This poses a particular risk for indigenous vegetation at high altitudes, especially if the vegetation structure has been damaged by previous fire or grazing.

Corsican pine can grow at altitudes over 900m. It seeds every three years and seed can survive on the ground for a few years before germinating in favourable conditions (North & Ledgard 2005). Today Corsican pine is mainly planted in shelterbelts. Its widespread use in historical plantings has led to it being the dominant wilding species in some areas with major spread including the Amuri Range (near Hanmer), Mount Cook Station along Lake Pukaki, and at Closeburn (west of Queenstown) (Ledgard 2005).

In a number of treeless high country locations regular sheep grazing has provided some control of wilding conifers. Figure 2 arranges conifer species in order of declining palatability for stock.

Declining palatability	**Conifer species**
	Radiata pine
	Ponderosa pine
	Contorta pine
	European larch
	Scots pine
	Douglas fir
	Corsican pine

Figure 2: Introduced conifers in order of declining palatability (Source (Ledgard & Langer 1999)

Radiata pine is the most widely planted conifer species in New Zealand. It is probably the most drought-tolerant of the common conifers (Ledgard 2005). Its spread is usually to warm north-facing slopes (often on steep rocky hillsides and bluffs) at higher altitudes. It is not a major wilding problem in the South Island High Country compared to some of the other conifer species, possibly because it cones are serotinous and there is usually insufficient heat to open them (Nick Ledgard, pers. comm.). Most radiata pine spread occurs in coastal and lowland locations (associated initially with radiata pine plantations). Places where radiata pine spread is common include Northland and Marlborough Sounds. Vulnerable environments include geothermal areas and a variety of lower stature coastal vegetation types.

Table 1 provides a summary of a variety of characteristics for those introduced conifer species that produce wilding conifers in New Zealand.

Table 1: Wilding Conifer Species Comparisons

Common name	Scientific name	Age of significant coning yrs	Coning altitude limit #	Spreading vigour	Shade tolerance	Palatability	Natural range
Contorta (lodgepole) pine	*Pinus contorta*	8	Above native treeline	Very high	intolerant (post fire regeneration)	High	W. USA
Scots pine	*Pinus sylvestris*	12	At native treeline	Very high	?	Moderate	Eurasia
Mountain pine	*Pinus uncinata*	8	Above native treeline	High	low	Moderate	Europe
Dwarf Mountain pine	*Pinus mugo*	8	Above native treeline	High	low	Moderate	Europe
Douglas-fir (Oregon pine)	*Pseudostuga menziesii*	12	1100m in NZ	Very high	moderate	Moderate	W. USA
Corsican (Black) pine	*Pinus nigra*	13	800m in NZ	High	intolerant	Least	Europe
European larch	*Larix decidua*	12	Not confirmed for NZ	Moderate	intolerant	High	Europe
Ponderosa pine	*Pinus ponderosa*	13	Not confirmed for NZ	Moderate	intolerant	Very high	W. USA
Muricata (Bishop) pine	*Pinus muricata*	12	Not confirmed for NZ	Low	Intolerant ((post fire regeneration)	High	W. USA
Maritime pine	*Pinus pinaster*	10	Not confirmed for NZ	Moderate	Intolerant (post fire regeneration)	Very high	Mediterranean
Radiata (Monterey) pine	*Pinus radiata*	10	600-700m in NZ	Low	intermediate	Very high	W. USA

Coning altitude limit is for New Zealand unless otherwise qualified, compiled from various sources

2.4 Environmental factors affecting wilding conifer spread capacity

Environmental factors affect the extent to which the spreading characteristics of a particular conifer species will be expressed in a particular location at a particular time. Key environmental factors affecting wilding conifer spread include:

- topographical position of the source populations (e.g. conifers located on a ridge crest (a take off site) are more likely to spread than those in valley bottoms)
- the shape of the source populations relative to the direction of the prevailing winds (where source population presents a long axis to the wind this increases the size of the downwind area vulnerable to wilding conifer invasion
- wind strength and direction (especially the direction and magnitude of periodic very strong winds that can carry seed long distances)
- frost and drought (these can affect seedling survival, especially for some species)
- vegetation type in areas downwind of the source population(s) (in general low stature vegetation is at more risk than is tall vegetation)
- density of downwind vegetation (open, especially low stature, vegetation is more at risk from introduced conifer invasion than is dense vegetation)
- land management practices in areas downwind of source populations. The regular grazing of grassland by sheep at stocking levels greater than 0.5 stock units per hectare makes an area less vulnerable to wilding conifer invasion than occurs with lower stocking levels Beneke 1962)

Most wilding conifer spread is downwind (considering the most prevalent wind direction) from the source population. However, occasional very strong winds from unusual directions can lead to occasional long-distance spread in different directions. This happened during the strong south-easterly winds associated with Cyclone Giselle (April 1968) where conifer seed was transported from Hanmer Forest to a variety of locations including the Amuri Range and the Clarence Valley.

3 History of wilding conifer establishment and current extent in New Zealand

3.1 National historical overview

Maritime pine was probably the first pine species introduced into New Zealand, shortly before 1830 (Richardson & Higgins 1998). Radiata pine, Scots pine and macrocarpa (*Cupressus macrocarpa*) followed in the 1860s. In 1871 the Government passed the Forest Trees Encouragement Act promoting plantations (Roche 1990).

Introduced conifers were recorded as naturalised in the late 1800's (Smith 1903), with Cheeseman (1925) reporting seven species as reproducing "very freely". Several introduced conifer species were described as invasive relatively early (1903 and 1913 for maritime pine and radiata pine respectively) (Thomson 1922). A variety of early twentieth century authors recorded spread from macrocarpa (*Cupressus macrocarpa*), radiata pine, maritime pine, Scot's pine and *Pinus halepensis* (Hunter & Douglas 1984). The area affected by wilding conifers increased substantially from the late 1940's (Hunter & Douglas 1984). For example, Beauchamp (1962) described the spread of ponderosa pine, Corsican pine, Larch and Douglas-fir in a number of Mackenzie Basin sites. His work indicated almost all of the trees had established in or after the 1960's, approximately 65 years after the initial trees had been planted. This delay between initial establishment and a species becoming relatively widespread occurs with many invasive plant species. The delay can be many years and can be caused by a variety of factors. In the case of introduced conifers an important factor is the time needed for the appropriate mycorrhiza to establish in the wild (e.g. Davis 2008).

Earlier authors suggested the increase in naturalised conifer spread in the South Island from the late 1940's could have resulted from dramatic reductions in stock grazing levels into the 1950's (following from previous severe overstocking) ; subsequent reductions in rabbit numbers leading to the spread of a variety of woody weeds; reduction in burning of tussock grasslands following burning restrictions introduced by catchment boards from the late 1940's ; and an increase in seed production as earlier plantings matured (Hunter & Douglas 1984).

During the 1960's *Pinus contorta* was seen invading large areas of the Volcanic Plateau in the Central North Island, including Tongariro National Park. An unpublished 1964 New Zealand Forest Service Report, summarised by Hunter & Douglas (1984), noted that the age structure of contorta pine spreading east from Karioi Forest on the Volcanic Plateau indicated dispersal from a single major seedfall about 1951-53. Density increased over the next decade. By 1975 contorta pine infestations covered 29,700ha (Hogg & Garrett 1975), compared to 10,900ha in 1963. In 2001 Ledgard (2001a) reported that approximately 100,000ha of the North Island was affected by wilding conifer regeneration, with most being in the Central Volcanic Plateau. At that time Ledgard was reporting the area affected by wilding conifers in the South Island as approximately 50,000ha.

Hunter & Douglas (1984) assessed 1976 and 1979 various catchment authority records (held by the Water and Soil Division of the then Ministry of Works) of introduced conifer spread in the South Island. At that time the species with the most reports were larch (16), contorta pine (13), radiata

pine (12), Corsican pine (11), Douglas fir (5) and maritime pine (5). In the 1970s many South Island wilding conifer stands were relatively small, although some were already large. For example, a 1976 report to the North Canterbury Catchment Board (Dick 1976) recorded that 5000ha of the Amuri Range (SE of Hanmer State Forest) had been invaded by predominantly Corsican pine and within this area moderate to high densities covered 960ha. In the Rakaia Valley a 10km long band of Corsican pine had invaded extensively grazed tussock grassland south-east of homestead plantings.

A map showing the locations of major areas of introduced conifer spread (>100 trees per hectare) in New Zealand as in 2001 can be found in Ledgard (2001a, 2004b). There are other areas affected by wilding conifers.

3.2 National mapping of current extent

There have been several projects mapping the distribution (and possibly density) of wilding conifer species at a national level or for the South Island. The most comprehensive of these projects was a jointly funded LINZ/Ministry of Agriculture and Forestry Sustainable Farming Fund project to determine the extent, density category and age category of planted and wilding conifers in the High Country/South Island (North et al. 2007). During 2006 information was collected in a variety of formats from a number of organisations (including the Department of Conservation, some forest owners, Ensis/Scion, Environment Canterbury, Marlborough District Council and Queenstown Lakes District Council).

The base layer for the South Island conifer map was the introduced conifer polygons from Version 2 of the Landcover Database (dated 2001/2). The datasets contributed by organisations usually covered small areas but were more detailed than LCDB 2 and so took precedence. Calculations were made to determine the area of introduced conifers that are planted, wildings or unknown origin that:

- Has cover which is dense (>30% cover), sparse (<30% cover) or unknown density (Table 1)
- Is coning (mature), immature or of unknown age (Table 2)
- Is radiata pine, Douglas fir, other/mixed species, unknown species, harvested forest, or young plantations
- Has received some form of wilding conifer control over the last 30 years (much of this control was incomplete) (Tables 2 & 3)

Using this information North et al (2007) mapped 760,000ha of the South Island as having some introduced conifer cover, of which approximately 580,000ha were mapped as intentionally planted or seeded, 36,300ha had an unknown origin and 145,000ha were mapped as wilding. Just under 50,000ha from all categories of planting, wilding and unknown origin (were mapped as having received some control in the last 30 years (as indicated by “C” in Tables 2 and 3)). Another 660,000ha were mapped as having received wilding conifer control at some stage over the last 30 years but densities in 2007 were too low to map. North et al. (2007) thought that these later areas probably had extremely low densities of wilding conifers and many areas probably still had scattered trees.

Including these extremely low density unmapped areas, North et al. (2007) calculated that there were almost 805,000ha of wilding conifer affected lands in the South Island. Paul and Ledgard (2011) estimated that approximately 300,000ha of land are affected by wilding conifers at various densities in the North Island. This North Island estimate was not based on a relatively comprehensive assessment such as that made by North et al. (2007).

This can be contrasted with South Africa where introduced conifer plantations cover 700,000ha, but proportion of area affected by wilding conifers is much larger. It is estimated that approximately 77,000ha are occupied by dense (100% cover) wilding conifers and there is a total affected area of 2.95 million ha (Le Maitre et al. 2000)

Table 2: The extent of South Island introduced conifers categorised by density and origin: hectares in each category where (C) is the part of the total that has received control. Source: North et al. (2007)

	Planted/seeded ha	**Wildings ha**	**Unknown origin ha**	**Total ha**
Dense (>30% cover)	579,000 (C 8,800)	13,300 (C 5700)	26,100 (C 2100)	619,000 (C 17, 600)
Sparse (<30% cover)		129,800 (C 28,400)	200	130,000 (C 28,400)
Unknown density		1800 (C 500)	10,000 (C 3200)	11,800 (C 3700)
Total	579,600 (C 8,800)	144,900 (C 34, 600)	36, 300 (C 5300)	760,800 (C 48,700)
Area controlled where no wildings mapped		(C 658,900)		

Table 3: The extent of South Island introduced conifers categorised by age and origin: hectares in each category where (C) is the part of the total that has received control. Source: North et al. (2007)

	Planted/seeded ha	**Wildings ha**	**Unknown origin ha**	**Total ha**
Mature (coning)	553,200 (C 5800)	100,100 (C 13,600)	31,900 (C 2100)	685,200 (C 21,500)
Immature	17,700 (C 400)	37,200 (C 18,300)	100	55,000 (C 18,700)
Unknown age	8700 (C 2600)	7600 (C 2700)	4300 (C 3200)	20,600 (C 8500)
Total	579,600 (C 8800)	144,900 (C 34,600)	36,300 (C 5300)	760,800 (C 48,700)

Collated information (North et al. (2007) has been used to compile various South Island maps showing the locations of planted versus wilding conifers, the locations of conifer species with different spread-risk profiles. Figure 3 is a single-scale version of the map that shows planted versus wilding introduced conifers. Figure 4 is a single-scale version of the map that shows locations of

introduced conifer species that have a high spread-risk profile and the locations of introduced conifers that have a low spread-risk profile. Figure 5 is a single scale version of the map showing the locations of planted versus wilding conifers for Otago Region. These three figures also show areas that have been subject to some wilding control during the previous 30 years.

Scalable versions of maps are on the New Zealand Wilding Conifer Management Group website (http://www.wildingconifers.org.nz/index.php?option=com_content&view=article&id=8&Itemid=18 accessed 5 June 2011).

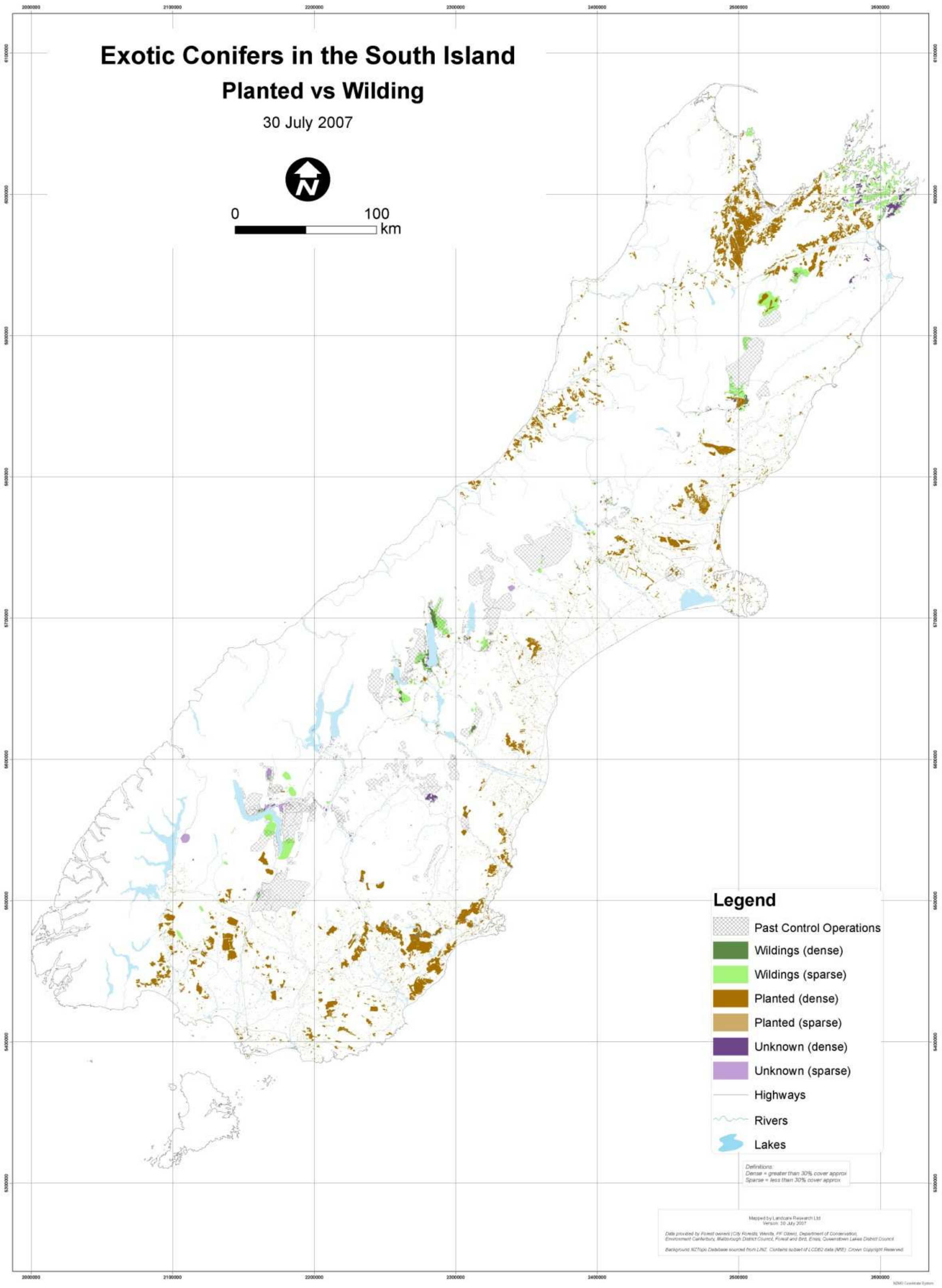

Figure 3: South Island planted versus wilding introduced conifers at two densities (dense >30% cover and sparse (<30% cover) as in July 2007 (Sources: North et al. (2007) and http://www.wildingconifers.org.nz/index.php?option=com_content&view=article&id=8&Itemid=)

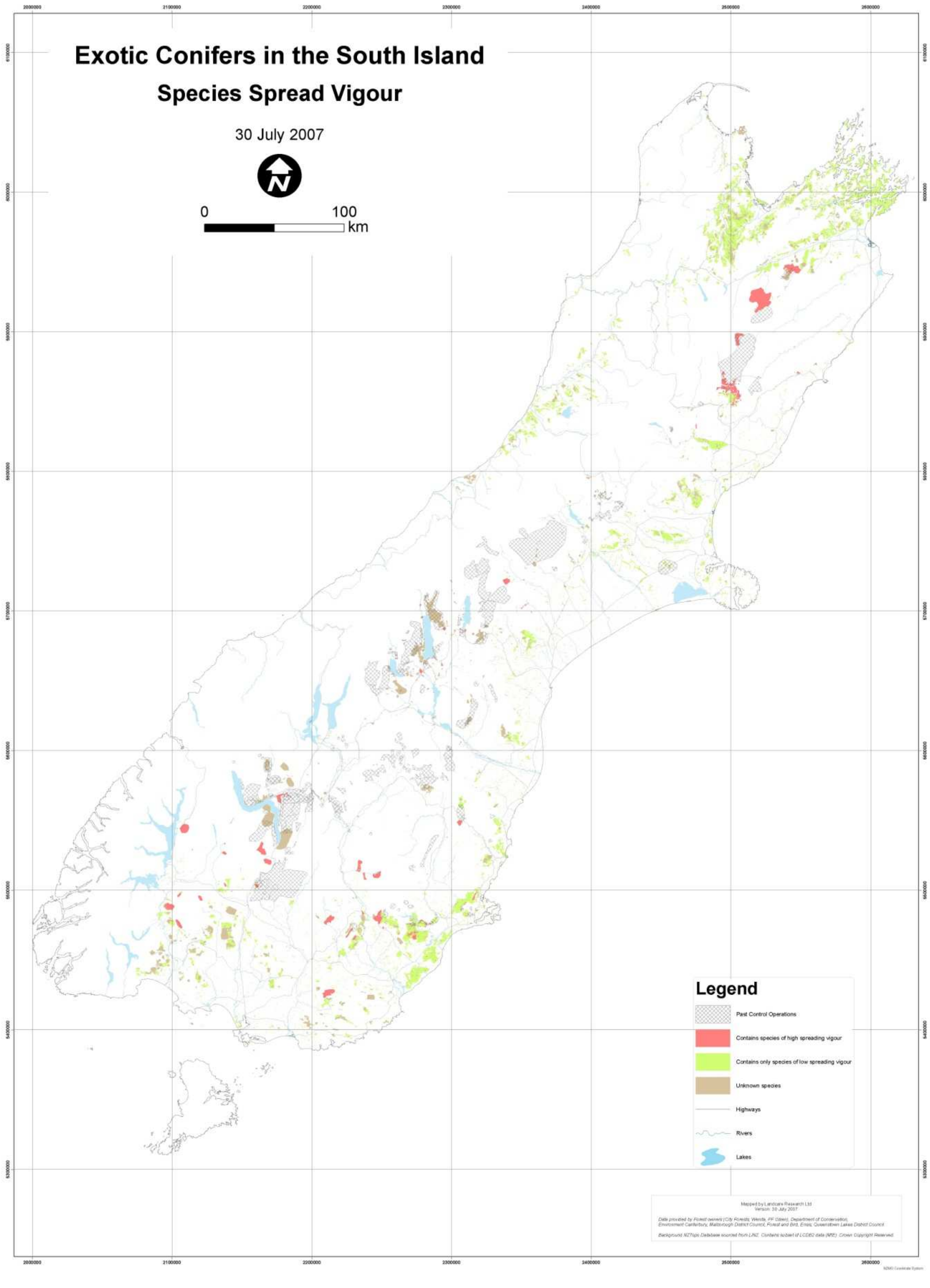

Figure 4: Introduced conifer spread vigour in the South Island as in July 2007 (Sources: North et al. (2007) and http://www.wildingconifers.org.nz/index.php?option=com_content&view=article&id=8&Itemid=)

Two Department of Conservation projects have mapped the national extent of several species of introduced conifers using different methodologies. Both projects extended beyond wilding conifers to include other environmental pest plant species. The first project by Benno Kappers mapped the national extent in 2007 of approximately twenty pest plant species, including two introduced conifer species- *Pinus contorta* and Douglas fir (Maps are in Appendix 2). Presence was mapped using polygons based on a variety of data sources including information provided by Department of Conservation field centre staff and others. Density was assessed/estimated for each polygon. The mapped assessments of the accuracy of the data show considerable variation. The map for Douglas fir shows large areas affected by low densities of Douglas fir in the south-eastern North Island and around Marlborough. This is not repeated by other assessments and is probably an artefact of the way data on presence and density was provided by some Department of Conservation field centre staff.

The second Department of Conservation project by Clayson Howell mapped the presence/absence of 180 environmental weed species within hectads (10km^2 grid squares) over the previous ten years. Four introduced conifer species were included- *Pinus contorta* , *Pinus mugo, Pinus nigra* and Douglas fir (Maps are in Appendix 3). Information sources are identified for each hectad (herbarium specimens, database records and expert opinion). Database sources included the Department of Conservation's BioWeb database and regional council electronic data. Experts were interviewed to determine the accuracy of the database data and to identify additional sites. For the overall project approximately half the hectad records were from pre-existing electronic datasets, with the remainder from expert assessment.

Summary Box 1: Amount of land affected by wilding conifers in New Zealand
The figures are confusing, in part because they have come from different sources. The best estimate for the South Island is that in 2007 about 805, 000ha were "affected" by wilding conifers. Of this, approximately 660, 000ha had been subject to control over the previous 30 years and current densities were very low and they could not be mapped. Another nearly 50,000ha of land had also received some confer control in the last 30 years but conifer density (in all mapped categories in Table 2) was still sufficiently high to map . Another 110,3000ha were mapped as having a wilding conifer cover without having significant control.

In the North Island it is estimated that 300,000ha are affected by wilding conifers at various densities. As with the South Island there are large areas that have been subject to control operations over different periods of time.

3.3 Regional and local mapping and monitoring of extent

Regional councils that include one or more species of introduced conifer in their regional pest management strategy (RPMS) generally have made some assessment of the extent of wilding conifers within their region. Some of these councils have set up a programme to monitor change in the extent of wilding conifers (and sometimes other attributes such as density, age category and species).

3.3.1 Canterbury

The Canterbury Regional Council monitors wilding conifer extent by catchment in the Region's "High Country". The first survey was from 1998-2003 (Old 2003). With ten years between monitoring periods for each catchment, the Council is part way through the second monitoring cycle. In the first survey the following parameters were assessed: the location of groups or individual wilding trees; field estimate of stem density for groups of trees; species composition and location of planted trees and whether there was fringe spread (Philip Grove, Canterbury Regional Council, pers. comm. 25 May 2011). Additional parameters assessed in the second survey include: the species of the wilding conifers (where possible); nearby land use, and most susceptible land use. The land use information is used to inform management, but is not quantified in the database.

Table 4 shows the changes in the extent of wilding conifers for five Canterbury high country catchments over the ten years between time 1 (1998-2003) and time 2 (2008-2013). Data for the time 2 measurements for the other five catchments in the programme had not been collected/analysed at the time information was collated for this report. The data for the first five catchments show that where there has been control within a catchment (usually control of low density populations over extensive areas) the extent of wilding conifers has generally reduced. In some cases there has still been an increase in the extent of the affected area even with some control work. For example, while there has been control in the upper Rakaia catchment, there has been significant wilding conifer spread around Mount Barker (Grove 2010). The extent of land affected by wilding conifers in the Waimakariri catchment also increased, even though there had been control operations between the two monitoring periods. There has been more intensive control of wilding conifers in this catchment since the time 2 monitoring in 2008 (Grove 2010).

Table 4: Extent of land affected by wilding conifers in the high country catchments for Time 1 (1998-2003) and Time 2 (2008-2013) where the measurements for a particular catchment are ten years apart. Source: Grove (2010)

Catchments (survey dates)	Survey Area (ha)	Hectares of land with a wilding tree 'outlier' presence	
		Time 1	Time 2
Waimakariri (1999; 2008)	219,673	2,501	6,096
Rakaia (1998; 2007)	247,160	1,359	3,098
Ashburton (1998; 2008)	93,882	1,298	802
Rangitata (1998; 2008)	147,837	325	161
Orari-Opuha-Opihi (1999-2009)	82,529	2,836	863

Figures 5-9 show the locations of planted and wilding conifers in the high country for the five Canterbury catchments addressed in Table 4. Source: Philip Grove, Canterbury Regional Council

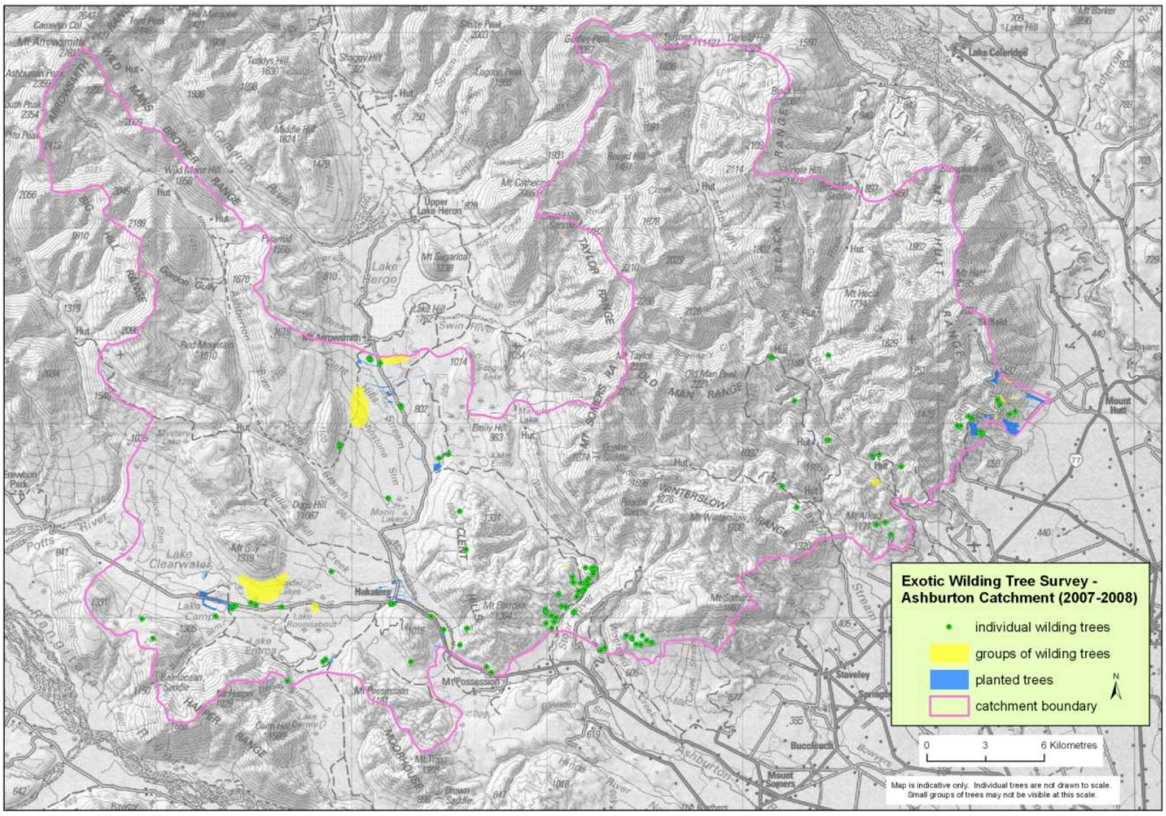

Figure 5: Planted and wilding introduced conifers in the Ashburton Catchment 2007-08. Source: Philip Grove, Canterbury Regional Council

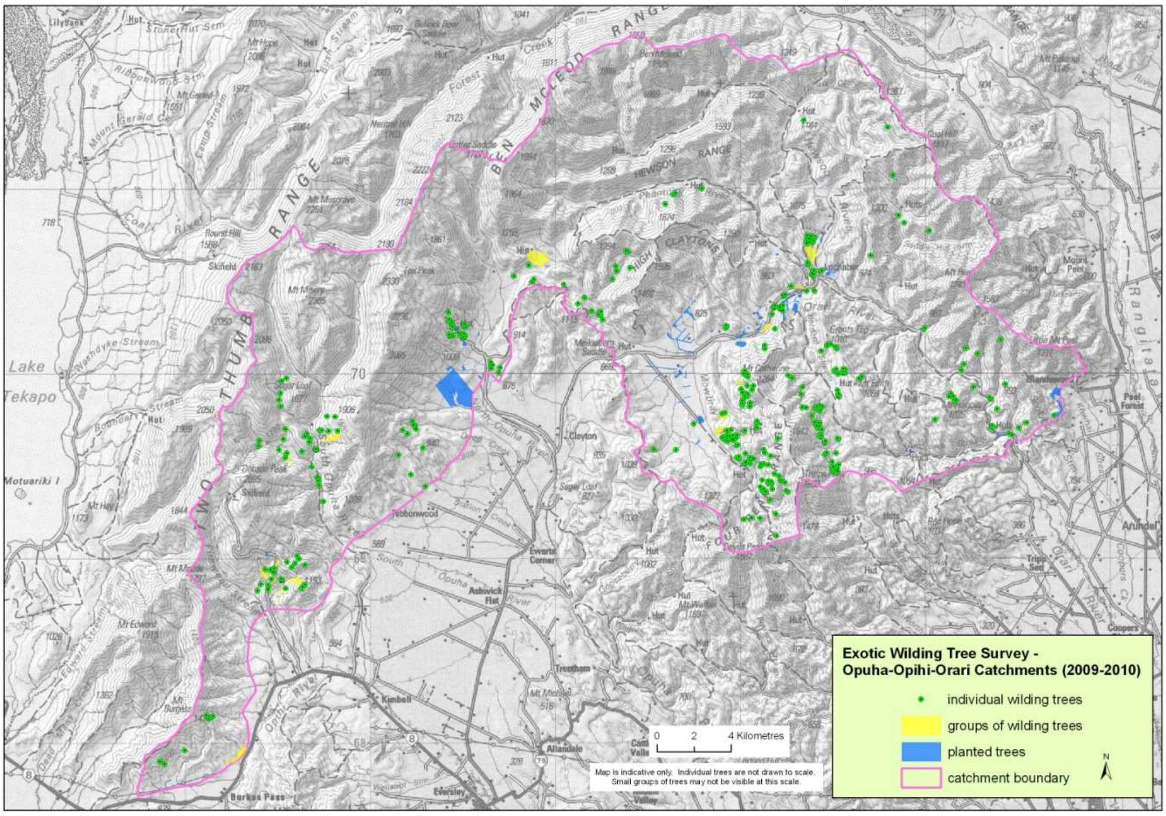

Figure 6: Planted and wilding introduced conifers in the Opuha-Opihi-Orari Catchments 2009-2010. Source: Philip Grove, Canterbury Regional Council

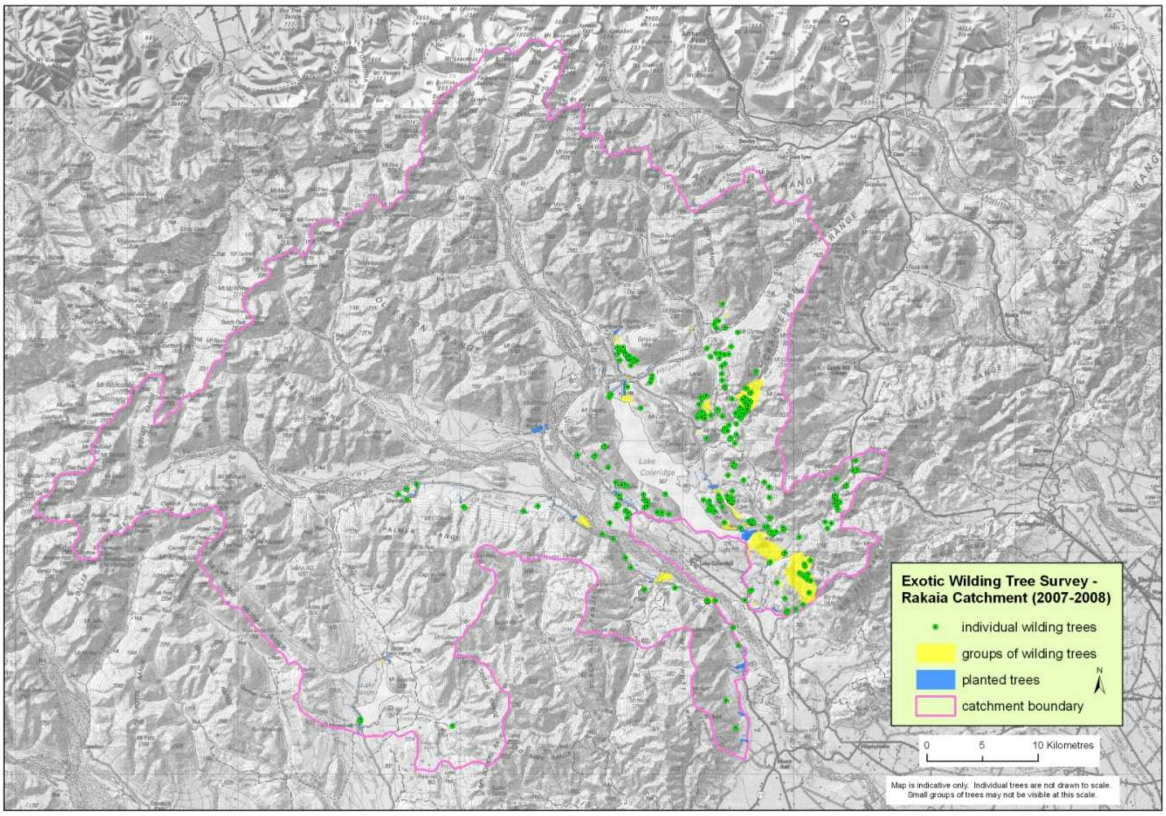

Figure 7: Planted and wilding introduced conifers in the Rakaia Catchment 2007-08. Source: Philip Grove, Canterbury Regional Council

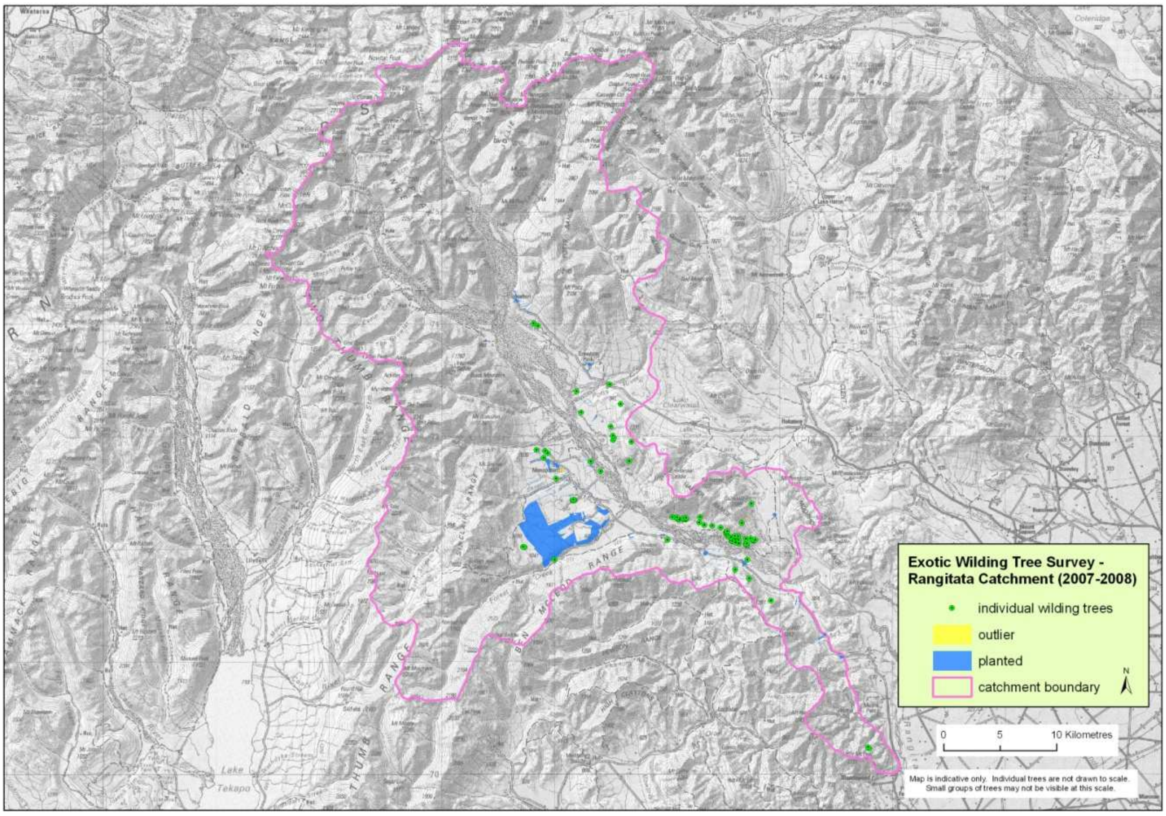

Figure 8: Planted and wilding introduced conifers in the Rangitata Catchment 2007-08. Source: Philip Grove, Canterbury Regional Council

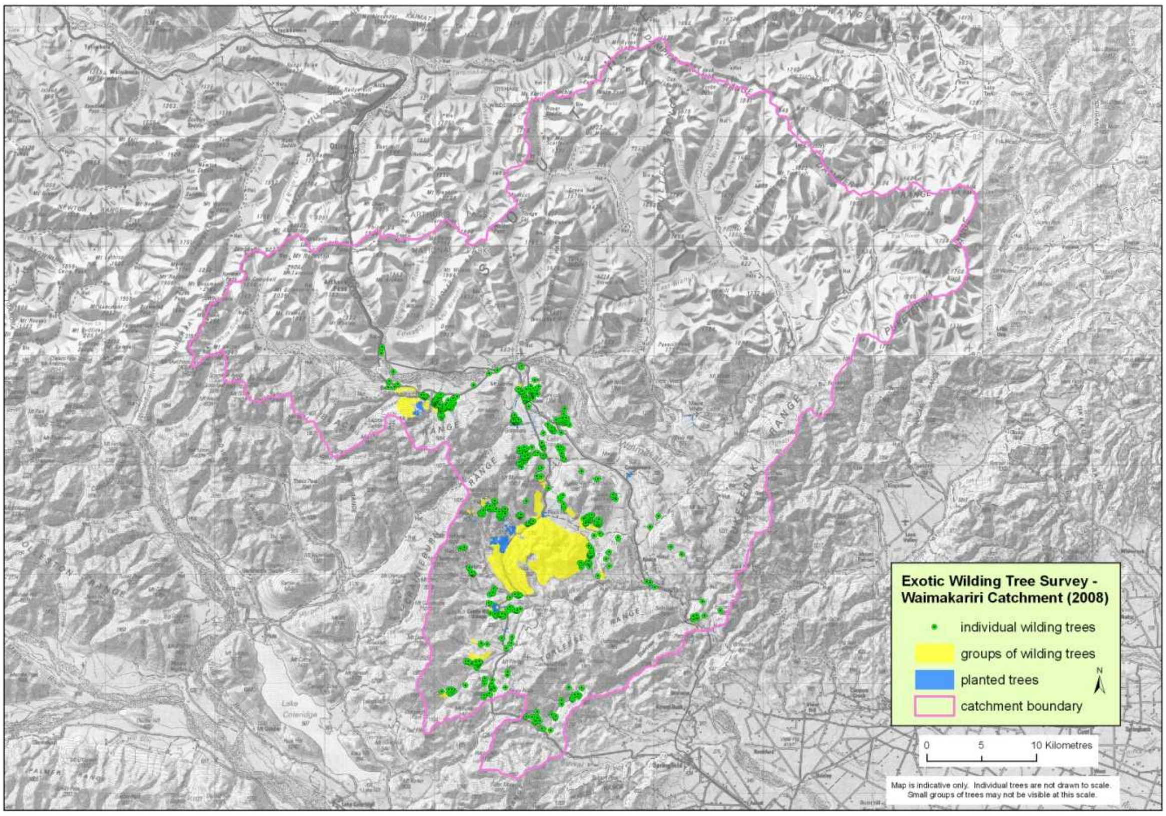

Figure 9: Planted and wilding introduced conifers in the Waimakariri Catchment 2008. Source: Philip Grove, Canterbury Regional Council

Wilding conifers in areas outside of the High Country are not measured/ monitored by the Regional Council (Philip Grove, Canterbury Regional Council, pers. comm. 25 May 2011). There are wilding conifers (mainly radiata pine) on Banks Peninsula. A small amount of site based (Department of Conservation and Christchurch City Council) control takes place around rocky outcrops on the Peninsula. Wilding conifers are not generally perceived to be a problem in the coastal environment, probably because much of the lowland and terrestrial coastal environment outside of Banks Peninsula is highly modified. Another unmonitored area where wilding conifers are present is the primarily dry scrub vegetation of the North Canterbury hill country (Philip Grove, Canterbury Regional Council, pers. comm. 25 May 2011).

3.3.2 East Taupo, Upper Mohaka, Rangitaiki, and Waipunga Catchments

This area lies within the boundaries of three Regional Councils: Bay of Plenty; Waikato and Hawke's Bay. The first assessment of *Pinus contorta* extent was made in 2000 and covered 250,000ha. Within this assessment area the extent of *Pinus contorta* was 10, 300ha (4%) in 2000. By 2011 the extent within this area had increased to 13,600ha (5%) (Wildlands Consultants 2011).

The second assessment in 2011 extended the assessed area to 486,000ha (Wildlands Consultants 2011). Within the 2011 area 27,400ha (6%) were affected with *Pinus contorta*. Wildlands (2011) estimated that up to another 2% of the area could be affected, primarily roadside margins (which were not all checked) in plantation forests. Densities varied from 1 tree/ha to >250 trees per ha. Protected natural areas made up nearly 70% of the land affected by *Pinus contorta*.

A comparison of *Pinus contorta* density changes between 2000 and 2011 for different categories of land tenure (Wildlands Consultants 2011) found that densities had generally reduced. This reflected the control operations by different organisations/land managers. For example, in 2011, 78% of affected Department of Conservation land had *Pinus contorta* densities of 1 plant per hectare, whereas in 2000 40% of the affected land had densities of 2-4 plants per hectare and 25% had densities of 5-30 stems per hectare. A major reason for the reduction was the intensive control work in the Waipunga catchment reducing *Pinus contorta* densities from 5-30/ha to <1/ha. By 2011 there were no Timberlands areas with >250 stems per hectare because the planted stands of *Pinus contorta* had been removed.

3.4 Wilding conifer establishment history and current extent at the regional level

3.4.1 Northland

Wilding conifers are well established in Northland and their range is increasing. The area affected is not known. Wilding pines are of particular concern in drier coastal areas and rare and vulnerable habitats such as gumlands and wetlands at Kaimaumau (Don MacKenzie, Northland Regional Council, pers. comm.). Contorta pine has successfully invaded a number of nutrient poor sites. Control operations for a variety of pine species (including one unknown species) at Whangarei Heads are ongoing.

3.4.2 Waikato

The situation for East Taupo is addressed in section 3.3.2. The Regional Council is assisting landowners in this area to control contorta pine (Kevin Loe, Waikato Regional Council, pers. comm.) Waikato Regional Council has been controlling contorta pine in the “alpine” parts of the region (non-Department of Conservation land in the Kaimanawa Mountains, lands adjacent to the Desert Road and Tongariro National Park) since about 1997. With similar control by the Department of Conservation, Horizons MW and the Ministry of Defence on lands they manage/administer current levels are very low but ongoing surveillance will be required. (Kevin Loe, Waikato Regional Council, pers. comm.).

3.4.3 Hawke’s Bay

Most of the areas seriously affected by wilding conifers in Hawke’s Bay are lands managed by the Department of Conservation (Ledgard 2009b). The Department of Conservation (2009) estimated that within Hawke’s Bay there are 97,000 ha of “land under active wilding pine management”. Wilding conifer densities range from closed canopy to less than one stem per hectare. 98% of the affected land is within the Kaweka and Ruahine Forest Parks.

Several hundred hectares of plantation forestry land (managed by Pan Pac Forest Products) are also affected by wilding conifers. Most of this area is associated with roads, tracks and firebreaks close to *Pinus contorta* plantations that have now been removed (Ledgard 2009b). Ledgard (2009b) considered that, apart from the upper Rangitaiki and Waipunga catchments (which straddle Hawke’s Bay, Bay of Plenty and Waikato regions), the private and Regional Council land affected by wilding conifers was small and either “under control” or “capable of control”. The 79,000ha of Hawke’s Bay region within the upper Rangitaiki and Waipunga catchments are addressed in section 3.3.2.

The main spreading introduced conifer species in Hawke’s Bay is *Pinus contorta* (Ledgard 2009b). Almost all wilding conifer species in the Kaweka and Ruahine Forest Parks and the Upper Rangitaiki and Waipunga catchments are *Pinus contorta*.

Wilding conifers in the Kaweka Ranges originate from revegetation projects undertaken by government departments. Revegetation work was undertaken in the Kaweka Ranges because of concern about increasing erosion in the Tutaekuri catchment and subsequent downstream aggradation and flooding of the Heretaunga Plains (Cunningham 1974). From the mid-to late 1800s the vegetation of the Kaweka Ranges was considerably modified by fire and introduced animals. Soils composed of layers of young volcanic ash were vulnerable to erosion. Early visitors described the crest of the ranges as being highly denuded since the destruction of native scrub and grasses, with very large areas of bare rock.

The first revegetation trials were in 1948. Following an interdepartmental inspection in 1954, more comprehensive species trials began in 1957 following the construction of a nursery and small hut at Makahu Saddle. By the mid-1960s the New Zealand Forest Service began management scale revegetation, primarily by aerial seeding of contorta pine. Much of the bare ground east of the main range was aerially sown with contorta pine. This continued until 1978, after which concern about wilding conifers spread lead to the end of the programme (McKelvey 1995). The major direction of

spread since then has been to the east. This spread has been limited to some extent by the characteristics of the adjoining vegetation cover (Ledgard 2009b).

Revegetation in the nearby Kaikomata (Comet) Range was undertaken for the same reasons as in the Kaweka Ranges. The earliest trees were planted in the 1950s (McKelvey 1995). Most of the current wildings result from planting and aerial seeding south of Comet Hut in the 1970s and subsequent fringe spread. Large areas of spread-susceptible land (bare and lightly vegetated) exist to the east and south of this area (Ledgard 2009b).

In the Northern Ruahines, despite a history of burning and overgrazing leading to depleted vegetation cover and extensive areas of bare eroding surfaces (Cunningham 1979), there has been little deliberate establishment of introduced conifers (Ledgard 2009b). Apparently one area of contorta pine was seeded in the 1960s, and removed ten years later. Current levels of wilding conifers are very low reflecting ongoing DOC control as the area is very susceptible to spread from the Comet Range (Ledgard 2009b). Towards the southern end of the Ruahine Ranges patches of introduced conifers (radiata pine, mountain pine and contorta pine) have been planted on slips and in gully heads at scattered locations (Ledgard 2009b). Ledgard (2009b) reported that spread from these areas was not significant (possibly because of high rainfall reducing coning effectiveness and encouraging local (native) vegetation growth. The areas of planted radiata pine (and associated pine regeneration) on the eastern margins of the range were programmed for removal (Ledgard 2009b).

The Warawara Range had a similar history of land use to that found in the Kaweka and Ruahine Ranges. Burning and overgrazing led to native vegetation loss and large areas of bare ground. The area also carried high numbers of goats. New Zealand Forest Service and Hawke's Bay Catchment Board concerns about extensive areas of erosion on the range crests led (in 1970) to the first direct seeding trial of radiata pine on 36ha in the south eastern portion of the ranges (Cunningham & Austin 1974). Following on from this "promising" trial, an area of 844 ha was sown with conifer seed between 1974 and 1976. The main conifer species was radiata pine, with some contorta pine (Ledgard 2009b). Another 190 ha was to be treated with a grass clover fertiliser mix. Ledgard (2009b) concluded that while the information was contradictory, aerial seeding of radiata pine did occur, though the exact area was unknown.

Today, the strips of radiata pine, predominately along the ridge crests are obvious with patches of fringe spread. Ledgard (2009b) considered that it was unclear whether the wildings in the intervening unsown land had spread from the original strips or from the planted Pan Pac forest below. He concluded that while there was plenty of susceptible land, invasion was slow.

In 1948-1958 the New Zealand Forest Service began small trial plantings of conifers on the Blowhard Plateau in Kaweka Forest (McKelvey 1995). Major plantings of radiata pine began in 1964, with significant amounts of Douglas fir and other species including contorta pine. There has been spread from the contorta pine plantations. Contorta pine was sown outside of the plantation area in the 1970s, mainly for erosion control purposes. Contorta pine wildings have since spread eastwards from these sowings. Pan Pac is removing wilding conifers from riparian areas and intended or has now removed all stands of contorta pine (Ledgard 2009b).

In 2009 the upper Taruarau River catchment had a low-density of widely spaced wilding conifers, almost all contorta pine. Ledgard (2009b) considered the most likely source of these wildings was trees in the Central Plateau/Karioi area (40km away). There were also some radiata and Douglas fir wildings, probably from local farm plantings.

The recent monitoring of wilding conifer extent in the upper Rangitaiki and Waipunga catchments was discussed in section 3.3.2. This area includes private farmland where contorta pine that had been originally planted as shelterbelts, has become a source of wilding conifers. There may also have been some long-distance spread from plantations in Kaingaroa Forest. The original spread from farm shelterbelts into areas of undeveloped land had been allowed to mature and spread further. Prevailing winds have meant virtually all the spread has been to the east affecting large areas of low stature monoao (*Dracophyllum subulatum*) administered by the Department of Conservation.

Western plantation forest land is primarily managed by Timberlands (Kaingaroa) with a smaller area administered by Taupo District Council. Wilding spread is dominated by contorta pine, mostly associated with early Kaingaroa plantations. While the planted stands of contorta pine were to be removed by 2010, the progeny still exists along roads, and gullies and riparian areas.

3.4.4 Wanganui- Manawatu Region

The changes in the distribution and density of wilding conifers on the 63,000 hectares of lands administered by the Ministry of Defence near Waiouru are addressed as part of a case study (Refer, Appendix 11.3). The Tongariro- Whanganui -Taranaki Conservancy of the Department of Conservation (part of which is within the Wanganui-Manawatu Region) controls wilding conifers on 132, 236hectares on a three year rotation (Appendix 8).

The Department of Conservation has removed contorta pine planted or seeded onto slips in the western Ruahine Ranges. It has also removed a large number of scattered trees from the tussock tops in the central and northern Ruahine Ranges. This includes the Aorangi-Awarua Trust land to the north. The most significant remaining stands of contorta pine are in the lower Pohangina River and its tributaries in the southern Ruahines.

Table 5 contains a catchment based summary of areas infested by contorta pine. There are a total of 78,500 hectares excluding the areas administered by the Ministry of Defence and the Department of Conservation. Infestations are now generally light or scattered with patches of dense infestation. These areas have been subject to varying types of control for different time periods as set out in the table. Some areas have been under active control since the early 1990's.

Table 5: Manawatu-Wanganui Region (Horizons) contorta pine infestation areas *excluding lands administered by the Department of Conservation and Ministry of Defence

Area Name	Area Location	Area Infested	Species	Estimate of density	Control if any
Upper Rangitikei	Southern Kaimanawas/ Rangitikei catchment south to Springvale Bridge on Taihape Napier road.	36,000 hectares	Pinus contorta	Scattered	Under active control since 2006
Otupae Range	Otupae range/Rangitikei catchment south of Taihape napier road	9,000 hectares	Pinus contorta	Scattered	Under active control since 2009
Ohinewairua Station	Taihape Napier Road	1,500ha	Pinus contorta	Scattered with some dense stands	Progressively controlled since 2008
Waiouru/Whangaehu	Around Waiouru township and Upper Whangaehu catchment	8,500 hectares	Pinus contorta with other wilding species present	Scattered with some shelter belts	Progressively controlled since 2008
Owhango/Raurimu	West of National Park village	1,000 hectares	Pinus contorta		Under active control since 2005
National Park/ Otamangakau	North West of National Park village	3,500 hectares	Pinus contorta	Scattered with some dense areas	Occupier and Horizons active control
Horopito	South of National Park village	3,000 hectares	Pinus contorta	Scattered	Under active control since 2010
Waimarino	Raetihi, Ohakune and Rangataua	5,000 hectares	Pinus contorta	Scattered	Under active control since 2010
Ruahine/Tararua vicini	Areas near Ruahine and Tararua ranges	minimal	Pinus contorta	Sparsely scattered single trees poss orginating from historic shelter rows	Under active control since early 90s
Karioi Forest	Karioi	11,000 ha	Pinus contorta	Majority scattered, some mixed radiata and contorta stands remain but no spread has been observed.	Under semi control since early 90s and managed programme since 2007

Table prepared by Malinda Mathewson, Horizons Regional Council*

3.4.5 Marlborough South:

Wairau catchment

Upper Wye catchment: Erosion control plantings totalling 370 hectares started in 1959 and continued to the mid-1980s. In addition erosion control aerial seeding totalled 30 ha. Species included contorta pine, western white pine, dwarf mountain pine and Douglas fir. By 2002 the area affected in the Wye and Waihopai catchments totalled 7000 ha, mostly contorta pine and western white pine on Department of Conservation land (Ledgard 2004c).

Upper Waihopai: Erosion control aerial seeding in the early 1970s included 510 ha of radiata pine and Douglas fir, while erosion control plantings of Douglas fir and five pine species totalled 5 ha. By 2002 there was 170 ha with erosion control aerial seeding, 10 ha with erosion control planting and 80 ha with wilding pines (Ledgard 2004c).

Branch/Latham catchments: These have been the target of more erosion control revegetation operations than any other single catchment in New Zealand, with 55,000 ha planted by the New Zealand Forest Service. Erosion control plantings started in 1963 with 1.8 million trees planted by 1986, and 1500 kg of conifer seed sown. Eleven main conifer species were planted, together with exotic broadleaf species. Extensive areas of the catchments are now covered in contorta pine, mountain pines and Douglas fir (below 1300 m elevation). The main areas affected are conservation land now managed for containment (Ledgard 2004c).

Raglan Range: Revegetation operations covered 300 -400 ha between the 1970s and mid-1980s. The main species included Douglas fir, both mountain -pine species, other pines and larches (but no contorta pine). The most vigorous spreading species were Douglas fir, mountain pines and stray contorta pine wildlings. The main areas affected are managed by the Department of Conservation for containment purposes(Ledgard 2004c)).

Taylor, Fairhall, Omaka and lower Waihopai catchments: There are patchy conifer plantations (no total area), mainly of radiata pine. There are some wilding outliers, mainly lone pines but with some areas of Douglas fir (Ledgard 2004c).

Mid Wairau: Considerable areas of the mid catchment contain radiata pine plantations. These now have outliers of lone pines (Ledgard 2004c).

Upper Wairau: Shelter belts and plantations are the primary sources, with mainly radiata pine and Douglas fir in the lower section and Scots pine and contorta pine in the upper reaches within Molesworth Station. The outcomes include 210 ha of “infestation sites” which need Department of Conservation control, together with scattered outliers elsewhere (Ledgard 2004c).

Awatere catchment

Early farm homestead plantings were patchy and were joined by a few larger plantations lower in the catchment. The outcomes include fringe spread and lone outliers, mainly radiata pine with some blocks of Douglas fir (Ledgard 2004c).

Upper Clarence catchment (including much of Molesworth Station)

Initial tree planting was associated with farm homesteads, with the first conifers being planted at Tarndale in 1891. The second phase between 1941 and 1958 was to establish shelter belts and plantations of a wide range of species, especially contorta, Ponderosa, and Corsican pines and larch, totalling 50,000 seedlings. A pause in plantings started in 1959 when contorta pine spread became a concern and three areas or shelter belts were clear felled. The third phase of planting began in 1966 resuming shelterbelt and plantation establishment using mainly Scots, Corsican, and Ponderosa pine. In total over 300 ha was planted (Ledgard 2006a).

Over 50,000 ha of Molesworth have been "affected" by wilding pines, of which over 1300 ha has been “significantly” affected (more than 100 wildings per hectare) (Ledgard 2006a). Wildings of contorta pine, Scots pine and dwarf mountain pine are of greatest concern. The areas of major wilding spread have been at Tarndale (Scots pine) and the Jacks/Jollies passes (Scots pine, Corsican pine and larch). Containment and control zones were proposed in 2004 (Ledgard 2004c), and there has been considerable implementation since then (Nick Ledgard, pers. comm.).

Flaxbourne/Waima catchments.

The early establishment of farm woodlots and shelterbelts used mainly radiata pine. The resultant low density and outlier pines are not considered a significant risk (Ledgard 2004c).

3.4.6 Marlborough North

Historical opportunities for wilding conifer invasion have been the greatest following: retirement from grazing; disturbance by storm events; landslides and fire; and forest-harvest. Since the mid-1980s large areas have been acquired for plantation establishment and planted mainly in radiata pine, totalling some 47,000 ha. Conifer spread in north Marlborough (especially the Marlborough Sounds) has been dominated by radiata pine aged 20-30+ years sourced from the extensive seed sources associated with plantations and woodlots. Nine other significant conifer species are recorded as wildings in north Marlborough, with the most common being maritime pine originating from old homestead plantings. Smaller areas of wilding conifers include: Bishop’s pine originating from small plantations and homestead plantings; contorta pine in the Rai area and south of Red Hills together with Douglas-fir from plantations in the Rai and Northbank areas (Ledgard 2004a).

The greatest area affected by wilding conifers is in the Marlborough Sounds, but smaller areas also occur within the inland catchments north of the Wairau River. The processes of spread in North Marlborough are almost entirely by wind. “Fringe” spread out to 200m from seeding trees is inevitable unless suppressed by grazing or native regeneration. “Distant” spread to several kilometres is driven by infrequent wind events, exacerbated by the turbulent eddies and updrafts generated by the relationship between the prevailing westerlies and the topography of the Sounds. Establishment has generally been more successful on the north facing slopes than the south facing slopes. This is because the north slopes were more likely to have been grazed and native regeneration suppressed for longer following destocking of marginal farms; and radiata pine is better adapted to the warmer and more drought prone northern slopes.

The existing distribution and density-classes of wildings in the Marlborough Sounds have been mapped and tabulated (Ledgard 2004a). In 2004 high densities (>50 stems/ha) covered nearly 1000ha, medium densities (1-50 stems/ha) covered 15,500ha, the low density areas (<1 wilding/ha) included nearly 24,000ha. The identified priority areas for control were mainly along the flanks of the Sounds, Durville Island and some of the smaller inner islands.

In recent years the Marlborough Sounds Restoration Trust has developed and managed wilding conifer control programmes for the Marlborough Sounds and D'Urville Islands. Initial control (largely by drill and injecting poison) has largely been completed for the inner Queen Charlotte Sound (http://www.soundsrestoration.org.nz/management-plan.html Accessed 10 December 2011).

In 2004 about 6500ha of the inland north Marlborough had some degree of wilding cover, with priority areas for control including Red Hills ridge, East Goulter Reserve and Dun Mountain (Ledgard 2004a). Ledgard (1996) stated that all the introduced conifers on Gordons Range (within the Mt Richmond Forest Park) had established from seed blown in from the nearby Golden Downs Forest, although others have observed that there are old plantings with the Forest Park itself that are also responsible for producing wildings (Andrew Karalus, Nelson Forests, pers. comm.). Most of wilding conifers were in open tussock and low scrub at 800-1100m elevation and included Douglas fir, Corsican pine, contorta pine, radiata pine and Scots pine. Ledgard (1996) thought it likely that introduced conifers would become the dominant cover in tussock and shrublands below 1200m.

The 11km Beebys Ridge (also within the Richmond Forest Park) has a history of fires and (sheep and then deer) grazing leading to induced erosion. From the late 1960's to late 1970's hundreds of hectares were planted in a wide range of introduced conifers including contorta pine and especially dwarf mountain pine *(P. mugo*) (Ledgard 2001b). (Ledgard 2001b) reported that the vegetation 2km north and south of Beebys Knob was unique for its mixture of eastern and western floras and that the ultramafic rocks in the Red Hills supported a limited and unique flora. The threat of wilding conifer invasion from the revegetation plantings on Beebys Ridge were considered greatest for the Red Hills (Ledgard 2001b). Since the 1990s there has been active control of the conifers. Ledgard (2001b) reported that most of the original contorta pine plantings had been removed (and wildings were being controlled), the few mature Douglas fir had been removed, and most wilding dwarf mountain pine had been removed (Ledgard 2001b). The planted dwarf mountain pine had not been removed because of the higher costs. Others have observed that there are still plantings along Beeby's Ridge and around Mt Patriarch that are likely to still be contributing to the wilding problem (Andrew Karalus, Nelson Forests, pers. comm.).

In 1996 Ledgard identified most of the wilding conifers in the Red Hills area as coming from Golden Downs Forest. Others have noted that the early plantings in Golden Downs Forest of spread-prone species (including contorta pine) were by the New Zealand Forest Service and that these had established a seed population inside the Park before the 1990s (Andrew Karalus, Nelson Forests, pers. comm.). A limited area was aerially seeded in 1972 with most trees removed in the late 1980s (Nick Ledgard, pers. comm.)

Current wilding conifer issues for the Mount Richmond Forest Park are discussed in Brown et al. (2010). A resurvey of the current extent of the wilding conifer problem in the Mt Richmond Forest Park by Nick Ledgard has been scheduled for the 2011/2012 summer. It is hoped that this will clarify the extent of the current problem and identify appropriate solutions.

3.4.7 Canterbury

Based on surveys of 2.4 million hectares of the western half of the region ("high country") during 1998-2003 (Old 2003) estimated that more than 60,000ha were affected by wilding conifers. The worst affected areas were the Mackenzie Basin, the Rakaia and Waimakariri catchments and the Amuri Range in the Hurunui District (Department of Conservation et al. 2010).

As described in section 3.3.1 this area is being progressively resurveyed. To date five catchments have been resurveyed (Grove 2010). Three catchments have shown a decrease (Ashburton: 1262ha (1998)-803ha (2007/08); Rangitata 246ha (1998)-161ha (2007/08); Orari-Opuha-Opihi 2836ha (1999)- 863ha (2009)). Two catchments have shown an increase (Rakaia 1366ha (1998)-3390ha (2007/08); Waimakariri 2500ha (1998/99)-6130 (2008)).

There have been assessments of wilding conifers at several locations within Canterbury Region. Such assessments are typically undertaken in the context of proposed management programmes. At Flock Hill Station in the Waimakariri Basin wilding conifers cover approximately 4000 hectares, with a considerably larger area downwind being at risk of future spread (Woods 2007). By far the most common species is contorta pine, with the other common species being mountain pine (*P. mugo*), Scots pine and Douglas fir. The three original plantings that are the sources for the current problem are: Craigeburn Forest Park, Flock Hill Station by Bridge Hill and the area surrounding Flock Hill homestead and lodge (Woods 2007). Planting in Craigeburn Forest Park for reforestation research purposes began in 1963 and continued into the 1970s. Plantings in the Bridge Hill area on public and pastoral lease land were established from 1979 to 1985 (Woods 2007).

The Broad Stream area in the Waimakariri catchment is a mixture of pastoral lease, freehold land the Department of Conservation Craigeburn Forest Park. The main source of wilding conifers for Broad Stream is the Cora Lynn Experimental Afforestation Area – The Arboretum which was planted between 1947 and 1951 (Hewson 2009). The main spreading species from here is Douglas fir. Between 1965 and 1971 approximately 85ha of eroding slopes between Broad Stream and Bruce Stream (Burnt Face Block) on the northern boundary of Craigeburn Forest Park were planted Douglas fir and Corsican pine (Ledgard 1989). Douglas fir is spreading rapidly into adjacent tussock land and into lower altitude beech forest where the canopy is disturbed (Hewson 2009).

Planting of a wide variety of introduced conifers in Hanmer Forest by the Government began in 1902. Spread was first observed in 1940 with dense fringe spread to a distance of 1km by Corsican pine (most prolific), larch (spreading the greatest distance), and a variety of other introduced conifer species. The first wildings appeared on the Amuri Range in 1945, with the major spread over the Amuri Range and Hossack Station beginning in the mid 1960's (Ledgard 1993b). Many thousands of hectares are affected by spread from Hanmer Forest, mainly to the south and east onto the Amuri Range and in the upper Hanmer River (Ledgard 1993a). In 1993 approximately 8000ha of the Amuri

Range area was affected by wilding conifer spread (Ledgard 1993b). Approximately 2250ha had a dense cover (>100 stems/ha), 2100ha had a medium density cover (10-1000 trees/ha), and 3650ha had a scattered or low density cover (1-10 trees/ha). The dominant species was Corsican pine (>90% in 1993) although a variety of other introduced conifer species were also present. Ledgard (1993b) observed that there had been little change in extent since 1986 because that most of the original seed source in Hanmer had been felled ten years previously and that most trees in the Amuri Range had just reached the age when they were capable of heavy coning. There was expected to be a considerable increase in seed production with both fringe and more distant spread. A recent assessment of the extent of the area affected by wilding conifers in the Amuri Range area is not available.

During the 1970s and 1980s over 1 million trees were planted for soil conservation, amenity, landscaping and recreational purposes associated with the construction of the Mackenzie Basin power scheme (Ledgard & Baker 1997). In a 1997 assessment, virtually all of 45 LINZ sites in the Mackenzie Basin were found to have at least one species with a high risk of spreading and Ledgard & Baker (1997) concluded that the risks of a major increase in spread was high. The most common species were Douglas fir, contorta pine, Corsican pine, Scots pine, mountain pine, Bishop pine, ponderosa pine, radiata pine, and Leyland cypress. Wildings were associated with the first six of these conifer species (Ledgard & Baker 1997). When Lake Pukaki was raised in the 1970s the Ministry of Works and Development planted trees to slow lake-shore erosion and for amenity purposes. In 1965 the Ministry determined to not plant further contorta pine because of the risk of spread. It does however appear that contorta pine was a “contaminant” in mixed pine plantings in the 1970s and that such plantings around the shores of Lake Pukaki have been a major source of wilding conifers in the area (Nick Ledgard, pers.comm.)

3.4.8 Otago

Information collected by North et al. (2007) has been used prepare a GIS map of introduced conifers in the Otago Region. This map (Figure 10) depicts the extent of the following three categories of introduced conifer within the Region: planted, wilding and unknown origin. Two densities are shown: dense stands (>30% cover) and sparse stands (<30% cover).

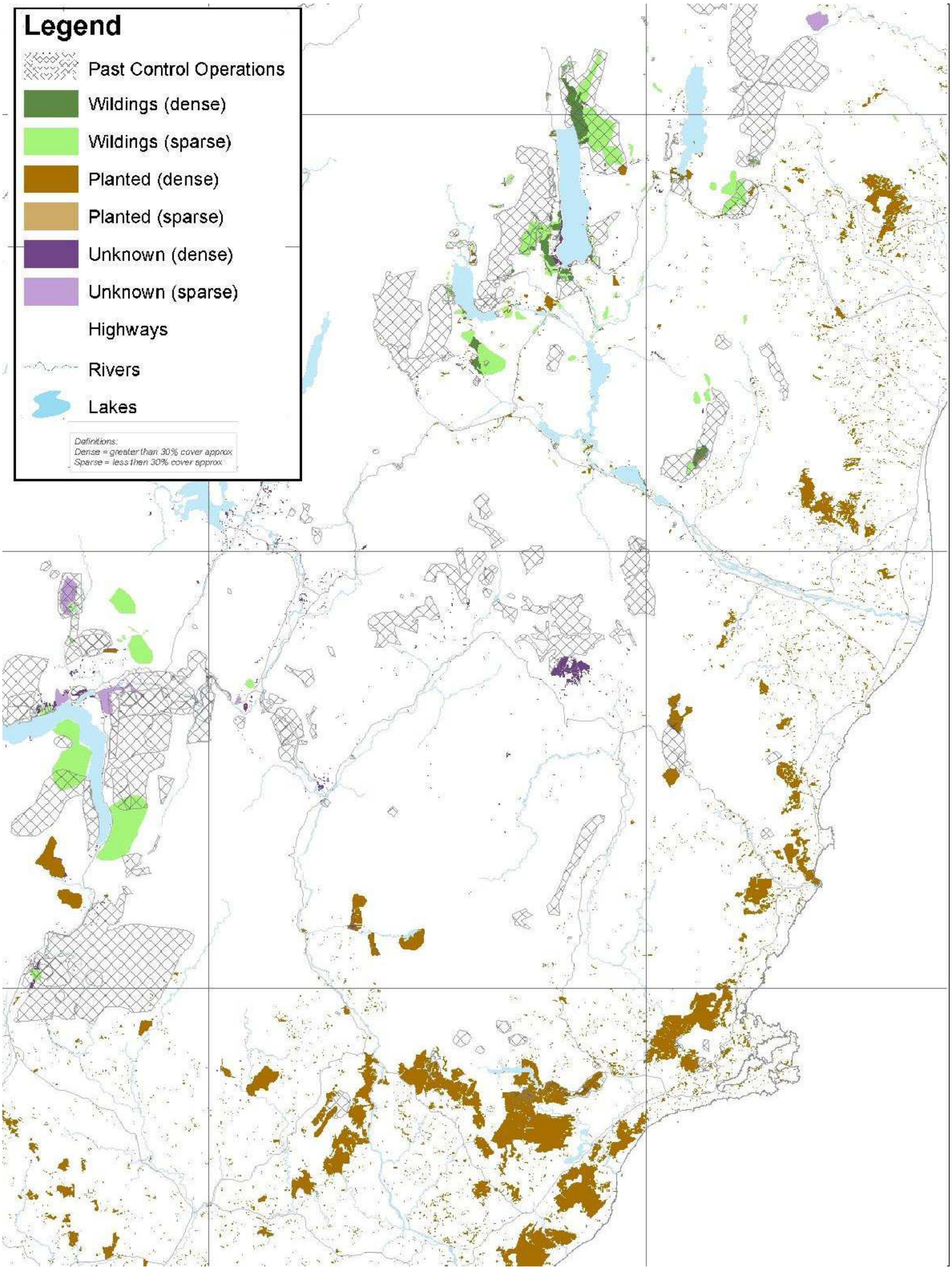

Figure 10: Otago Region planted versus wilding introduced conifers at two densities (dense >30% cover and sparse (<30% cover) as in July 2007 (Sources: North et al. (2007) and http://www.wildingconifers.org.nz/index.php?option=com_content&view=article&id=8&Itemid=)

There is a wilding conifer problem is on various lands administered by the Department of Conservation. Approximately 58,500ha of high country conservation park requires/is being treated for wilding conifer infestation and approximately 78,000ha of other conservation land in the Conservancy is threatened by introduced (mostly wilding) conifers and sometimes other weed species (estimate calculated from land register data provided by the Department of Conservation). There are also wilding conifer problems on other Crown lands and on private land.

A wilding conifer control strategy has been prepared for the Wakatipu area. Douglas fir was first planted in the Queenstown area in the 1870s. The conifer slopes behind Queenstown were planted and seeded with Douglas fir from the 1940s to 1960s and have regenerated naturally since then (Day & Ledgard 2009). In the Mt Aurum area introduced trees were first planted around the Skippers Cemetery in about 1880 and other small plantings were established close to the homestead and other local buildings soon after. Natural regeneration was relatively slow until the 9100ha area was declared a recreation reserve and retired from grazing (Ledgard 1990). In 1986 local councils established a 140ha commercial Douglas fir forest on slopes between Coronet Peak and Arrowtown. This forest is the source of wilding conifers some distance downwind (Day & Ledgard 2009). It is these blocks areas as well as smaller plantations, shelterbelts and other pockets of established wildings that form the source of wilding conifers in the Queenstown Lakes area.

The dominant wilding species in the Wakatipu catchment is Douglas fir. Contorta pine is widespread (Briana Pringle, Queenstown Lakes District Council, pers. comm.). In many parts of the catchment a cohort of trees probably resulted from the broadcast dispersal of seed in a southeast direction during wind events in 1979 and 1981. Since 2004 some significant new invasions have been observed and it is suspected that the seed for these invasions has come from new sources on exposed “take-off sites” (Day & Ledgard 2009). There is also second generation spread and pockets of contorta pine are also found within forested areas such as Queenstown Hill (Briana Pringle, Queenstown Lakes District Council, pers. comm.).

Mt Dewar Station is a high country freehold property of 1796ha in the Queenstown Basin that largely surrounds the Devils Creek Conservation Area. Up until the early 1970’s the Station was virtually free of wilding conifers spread, but since then there has been exponential expansion and by December 2003 nearly one-third of the southern part of the property was affected by wilding conifers (Norton & Ledgard 2007). Three factors (Norton & Ledgard 2007) were largely responsible for the increase in wilding cover:

- Reproductive maturing of wilding conifers distant from Mt Dewar that provide the seed source for long-distance dispersal onto the property
- Reproductive maturing of early wilding conifers on the Mt Dewar Station (so providing for more long distance spread and fringe spread)
- Lower stocking and lack of top-dressing since the early 1990s

Without control it was predicted that all of the station would have a significant wilding conifer cover within 80 years, with Douglas fir dominating (Norton & Ledgard 2007). It was also predicted that adjacent areas would be affected with the Devils Creek Conservation Area likely to be fully occupied by wilding conifers within 40-60 years. As there has been considerable wilding conifers removal since 2007 it seems likely that these predictions will not eventuate (Nick Ledgard, pers. comm.)

3.4.9 Southland

The majority of wilding conifers in Southland Region come from old New Zealand Forest Service experimental and erosion control plots, commercial forests owned by forestry companies and privately owned forests. The spread from these areas has had a major impact on public conservation land. As plantations are gradually being converted to Douglas fir, this is expected to lead to increased areas of wilding conifers (Lynne Huggins, Department of Conservation, pers. comm.). Department of Conservation budgets are capped and over the last few years have been reduced, so meaning that less funding will be available to control existing, let alone new areas of wilding conifers (Lynne Huggins, Department of Conservation, pers. comm.).

The highest profile Southland area for wilding trees is Mid Dome and its downwind surrounds, although there are large areas of wilding trees in other parts of Southland (as described below). The Mid Dome Soil Conservation Reserve was established by the then Soil Conservation and Rivers Control Council in 1947 (initially 425ha and later increased to 657ha). The reserve was established because the area was suffering from severe erosion and the shingle fans posed a threat to the main highway and railway line. Prior to the establishment of the reserve the area had been subject to many years of grazing and vegetation burning. After a variety of trials, 250 hectares of conifers (primarily contorta pine and mountain pine (*Pinus mugo*)) were planted the Ministry of Works and Development from the early 1950s to late 1980s (Mid Dome Wildling Trees Charitable Trust 2008). Today approximately 8000ha have a medium to dense infestation (100 to>2000 stems/ha). A further 60,000ha have a low density infestation (1-100 stems /ha) (Mid Dome Wilding Trees Charitable Trust et al. 2010). A major community/agency based control programme is being led by the Mid Dome Wilding Trees Charitable Trust. To date the spread has been contained and 40,000ha of lightly infested land east of the Mataura River has been cleared (Richard Bowman, Environment Southland, pers. comm.).

Juveniles from a plantation of *Pinus contorta, P. sylvestris* and *P.mugo* on the Cheviot Faces (north western flanks) of the Takatimu Mountains are spreading into the surrounding areas. Seed from the Douglas fir commercial forests planted in the mid 1990s on the north western faces and western faces of the Takatimu Mountains is invading the surrounding tussock grasslands administered by the Department of Conservation (Richard Bowman, Environment Southland, pers. comm.). Other areas within the Takatimu Mountains have isolated low density wilding pines.

Within the Te Anau Basin wilding trees (predominantly *Pinus contorta*) have spread into the Wilderness Conservation areas from old shelter belts (Lynne Huggins, Department of Conservation, pers. comm). While the wilding contorta pine and radiata pine in the Awarua Wetland have been removed, this requires ongoing monitoring.

There are low densities of wilding conifers (contorta pine, mountain pine, larch, Scots pine and Douglas fir within the Eyre Mountains, with Douglas fir invading from neighbouring plantations (Lynne Huggins, Department of Conservation, pers. comm.) The contorta pine, mountain pine, and Scot's pine at the Mt Bee historical soil conservation reserve has been cleared but ongoing maintenance is required (Lynne Huggins, Department of Conservation). Major new plantations in the Upper Mataura catchment include approximately 3500ha of Douglas fir planted at Cainard, Fairlight and Glenfellen stations from 2001 to 2003 (Ledgard & Palmer 2004). Here the highest risk

of ecologically damaging wilding spread is associated with spread from Cainard Station onto the Eyre Conservation Estate (Ledgard & Palmer 2004). The Glenfallen Plantation is now administered by the Department of Conservation and the trees are being removed with the intention of complete removal prior to coning (Lynne Huggins, Department of Conservation). If this is achieved the risk of spread to adjoining areas would be removed. West Dome has low to moderate levels of wilding Douglas fir from neighbouring forestry.

The Blue Mountains area (outside Southland Region but inside the Department of Conservation Southland Conservancy) has low to high densities of wilding conifers including Douglas fir, ponderosa pine, mountain pine and radiata pine (Lynne Huggins, Department of Conservation).

In the Catlins area, there has been spread of contorta pine, Ponderosa pine and Douglas fir from Venlaw Forest into surrounding tussock grassland. Densities of these wilding conifers is currently low (Lynne Huggins, Department of Conservation).

4 Impacts of wilding conifers

4.1 Overview of impacts on indigenous ecosystems

Wilding conifers grow faster and taller than low-stature indigenous vegetation. Indigenous ecosystems that are at particular risk from wilding conifer invasion include: tussock and other indigenous grasslands; alpine ecosystems; subalpine, dryland and other scrub and shrublands; monoao-dominated and other frost-flats, wetlands; turf communities; geothermal ecosystems and features; dunelands; ultramafic/serpentine areas; rockfields and herbfields; riparian areas; coastal margins; and bluffs and cliffs. Large areas in the eastern South Island and the Volcanic Plateau in the central North Island contain low stature native vegetation below the altitude of the local treeline formed by indigenous species. Climate change is likely to place increasing stress on some indigenous ecosystems and may make some more vulnerable to invasion by weed species including wilding conifers.

A number of the more invasive wilding conifer species (e.g. contorta pine, mountain pine and Corsican pine) are able to grow at altitudes above the local treeline formed by indigenous forest species (often mountain beech). Wilding conifers above the treeline formed by native species can not be replaced by native species as part of natural succession processes. With climate change subalpine and alpine ecosystems are likely to become increasingly stressed and their vulnerability to wilding conifer invasion is likely to increase. The altitudes at which wilding conifers could establish and reproduce are likely to increase.

Once wilding conifers invade low stature communities they shade out many of the native plant species and can change soil characteristics. Where the spread results in dense wilding conifer growth (usually from fringe spread) wetlands and riparian areas can become dry, especially in small catchments.

In some cases wilding conifer spread may lead to the local extinction of native plant communities. Examples of threatened communities include: the naturally stunted native shrubland communities on the Nelson Red Hills ultramafic substrates; and remnant shrubland and grassland communities in the intermontane basins of the South Island high country (Harding 2001). A Northland example is the gumlands and wetlands at Kaimaumau (Lisa Forester & Don Mckenzie, Northland Regional Council).

Dickie (2011) found that pines and beech shared only a few native mycorrhizae with a cosmopolitan distribution. Pines are co-invading New Zealand along with a number of non-native fungi, at least once of which is animal (deer) dispersed (Dickie et al. 2010).

Conifers can enhance soil mineralisation processes, thereby increasing the levels of available nitrogen, phosphorus and sulphur in the top 10cm of the soil (Davis & Lang 1991). Herbaceous plants (especially grasses) invading a site recently cleared of pines can grow very well for a few years. This has implications for some conifer control programmes. For example, in monoao

(*Dracophyllum subulatum*) frost-flats in the upper Rangitaiki and Waipunga catchments of Central North Island it has been found that where very large or dense conifers had been felled, the resident monoao and lichen (*Cladia* sp, *Cladonia* sp) died. The replacement vegetation was grasses and in some places *Hieracium* sp. (Ledgard 2009b). The dead areas were larger than would be expected from crushing. Ledgard (2009b) thought the nutrient flush resulting from the felling of conifers (Paul & Ledgard 2009) may be "toxic" to monoao (or its ericaceous mychorrhizae) which grows in nutrient-poor sites. Ledgard found places with large open "clearings" with a dense sward of introduced grasses growing through the decaying slash of felled contorta pine. The only live woody species were bird-dispersed coprosmas and pittosporums. Introduced grasses were found dominating some areas around decaying conifers felled 20 years earlier.

Douglas fir is still the only common introduced conifer species that is capable of invading canopy gaps in native forests (Ledgard 2006b). This is because of its higher tolerance of shade (Ledgard 2006b; Davis et al. 2011). Douglas fir is able to spread into shrublands and regenerating native forests before canopies close (Ledgard 2002). It is able to establish in mature beech forest (especially mountain beech), particularly where the beech canopies are more open/have a lower cover and the understory is relatively sparse (Ledgard 2006b; Davis et al. 2011). Where the canopy of mountain beech forest has thinned (because of old age or possibly an environmental stressor) that forest is more vulnerable to Douglas fir invasion. In that situation Douglas fir saplings can grow faster than beech (Thomas Paul, unpublished data). Once Douglas fir reaches the canopy it provides an ongoing seed source that could potentially lead to eventual replacement of the mountain beech forest by Douglas fir in that location.

Dehlin et al. (2008) compared the performance of planted tree seedlings and soil communities for Douglas fir, contorta pine and mountain beech in mono-dominant stands at Craigeburn Forest in Canterbury. They found that the seedlings performed best under mountain beech. Soil organic matter levels, microbial biomass levels, and the abundance and diversity of microbe-consuming nematodes were all highest under mountain beech. Dehlin et al. (2008) also found that nematode community assemblages found under mountain beech were very different to those found under contorta pine or Douglas fir. These results indicated that introduced conifers strongly reduced densities of organisms known to be important in regulating plant nutrients. Dehlin et al. (2008) concluded that the establishment of stands of contorta pine and Douglas fir in areas previously occupied by mountain beech would lead to a variety of above and below ground changes. These include negative effects on seedling survival and on components of the decomposer biota known to regulate ecosystem nutrient fluxes. The authors predicted that as introduced conifers invaded and subsequently dominated new landscapes it was likely that there would be fundamental changes in ecosystem properties above and below ground.

Plantations of introduced conifers can provide ecological benefits including habitats for indigenous bird species such as falcon (Seaton 2011), habitats for certain threatened plant and animal species (Pawson et al. 2010)) and benefits for stream ecosystems compared to agricultural land uses (Baillie 2011). Only some indigenous species find suitable conditions in stands of introduced conifers. In a comparison between native forests and plantations dominated by introduced conifers Clout and Gaze (1984) found that native bird diversity in the upper South Island to be lower in the latter.

Nectar and fruit eating species and hole nesting species did not find introduced conifer plantation forests to be suitable habitat.

The impact of wilding conifers on indigenous birds will be variable depending on location and the structure of the wilding conifer stand, and what land cover/use is being replaced. Some species (especially insectivorous species) may find increased suitable habitat with the establishment of more forest-like vegetation (compared to open low grassland). Other species are likely to find the habitat, including food sources, less desirable.

4.2 Impacts on vegetation patterns and ecological processes in South Island drylands

Rogers et al (2005) defined a New Zealand dryland zone to include those areas where high temperatures and high evapotranspiration create Penman annual water deficits greater than 270mm. The zone covers 19% (50, 555km$^{2)}$ of New Zealand's land area with most (39,200km^2) being in the South Island. Within this zone over 70% of the indigenous ecosystems have been lost (Walker et al. 2009a) and only 1.9% is protected as public conservation land (Rogers et al. 2005). Many of the native species present within New Zealand's "Drylands" are nationally or regionally threatened, concentrated in small refuges, often with reduced regeneration and limited resilience and compromised genetic structure (Walker et al. 2009a). Dryland ecosystems are at particular risk from wilding conifer invasion.

4.2.1 South Island dryland historical vegetation patterns and changes

Prior to the arrival of humans, forests and shrublands were extensive throughout most of the South Island drylands, with substantial grasslands confined to the alpine zone and dry terraces in intermontane basins (McGlone 2001). There is some disagreement over the extent of pre-human grasslands (Box 2), although the evidence indicates that their extent was limited below the treeline. Following the arrival of Maori 730 years ago (Wilmshurst et al. 2008) there was an unprecedented increase in fires compared to the pre-settlement Holocene (Rogers et al. 2007). By the time of early European settlement the dry interior of the South Island was virtually devoid of forest (Buchanan 1869).

Box 2: The extent of pre-human grasslands in the eastern South Island

While it has been established that woody vegetation was a major component of eastern South Island drylands prior to human settlement, there has been disagreement over the extent of pre-settlement grasslands below the treeline. In their assessment of 30 years of monitoring data of a narrow-leaved snow-tussock grassland (*Chionochloa rigida*) after it was retired from grazing, Mark & Dickinson (2003) found significant increases in tussock height and cover and only a slight non-significant gain in co-dominant shrubs. They concluded that that low-mid altitude snow-tussock grassland could be sustained for at least several decades and that in pre-human times there may have been a mosaic of woody and non-woody vegetation in inland basins. Wardle (1991) proposed that extreme climate (late summer water deficits and winter frost) excluded woody vegetation and maintained temperate grassland on dry basin floors.

Walker et al. (2004) used several data sources (modelling based of a database of existing species locations; subfossil-wood, charcoal and pollen records; and the presence of species in stressful environments) to conclude that water deficits and minimum winter temperatures are not sufficient to exclude tall woody vegetation from the intermontane basin and valley floors of central Otago. They concluded that low forest and shrublands would have dominated these environments (covering up to 80% of Central Otago's valley floors) prior to human settlement, with lowland grassland confined to floodplains and local areas of shallow or permanently moist soils. This meant that the extensive areas of short tussock grassland recorded in the Central Otago lowlands largely arose from retrogressive succession induced by fire following human settlement.

Walker at al. (2004) also argued that shrublands and tussock-shrublands were widespread above the Otago treeline and that relatively pure *Chionochloa* grasslands may have been restricted to summit areas. McGlone (2001) concluded that extensive *Chionochloa* tussocklands were most common above the treeline on the western side of the Southern Alps, and that a mixture of grasses and shrubs was more likely for the mountains of the dry eastern interior

Prior to human settlement natural fires were rare in New Zealand (McGlone 2001). The widespread fires following Maori arrival, led to the near-elimination of the unique fire-sensitive woody vegetation from all but the wettest districts and fire-sheltered microsites (McGlone 2001). This woody vegetation was replaced by fire-induced tussock grassland (e.g. *Chionochloa*), bracken and seral shrub communities (e.g. kanuka and manuka) (McGlone 2001). Large herbivorous birds (moas) were removed. This was the first major regime change for the vegetation (Walker et al. 2009a). From 1850 European settlement and widespread pastoral farming led to another major regime shift for the vegetation (Walker et al. 2009a). Initial annual burning of the vegetation further restricted woody plants, and introduced mammals restricted palatable plants to inaccessible refugia. The mosaic of woody remnants and tall tussock grasslands dominated by *Chionochloa* was replaced by short tussock grasslands dominated by less palatable *Festuca* and *Poa* species and more introduced species (Walker et al. 2009a). Introduced predators further reduced native birds and reptiles.

4.2.2 Introduced conifer impacts on dryland vegetation succession processes

Wilding conifers can significantly affect vegetation succession in South Island drylands. In the context of succession, species are often divided into two categories: early succession species that grow quickly, produce abundant seed and have opportunistic life histories (*r-selected* species); versus latter stage long-lived species (*K-selected* species) that are more competitive in the context of traits such shade tolerance. Some species do not fit into these categories. In particular, rapidly growing and relative shade-intolerant long-lived trees may lead to complete long-term suppression by a single species. Huston & Smith (1987) described these as "super-species". Vegetation modelling suggests that New Zealand has several introduced "super species" including fast-spreading introduced pines, Douglas fir and sycamore (Meurk & Hall 2006; Walker et al. 2009b).

Disturbances resulting from human settlement have had a profound effect on the indigenous woody flora of the South Island drylands, eliminating many formerly widespread woody species and

restricting others to small isolated relicts (McGlone 2001). Indigenous pollinators and seed dispersers for these woody species have also been extensively modified. This means that the re-establishment of many formerly common woody native species is likely to be slow or non-existent. Those woody species that colonise the dryland grasslands today must tolerate: conditions that are dry and droughty, mammalian browsing, and occasional fires; and they must compete successfully with grasses (Walker et al. 2009b). Few indigenous species have these attributes which are more common amongst introduced species (Wardle 1985). Walker et al. (2009b) expected that dryland secondary woody vegetation would be susceptible to dominance by various woody species such as pines, Douglas fir, sycamore, larch and birch over extended time periods, especially in sites that are drier, have more frequent disturbance, and have no/minimal seed sources for the taller indigenous species.

The potential woody vegetation for severe inland environments is relatively short and open. Walker et al. (2009b) concluded (after a vegetation succession modelling exercise using data from an extensive network of plots) that successful succession towards indigenous woody vegetation would require the control of fire and ecosystem transforming weeds (especially Scotch broom, gorse and pines), especially in inland drylands. They also concluded that while the species composition of the emerging indigenous woody vegetation will vary from pre-settlement times, over time the relatively similar structure should reduce invasions by light-demanding introduced species.

In summary, the impacts of wilding conifers on succession in the South Island inland drylands is likely to be greater than for locations where rainfall is higher. Wilding conifers in this environment are "transforming weeds" that change the environment both for low stature tussock grasslands and for areas where succession to indigenous woody vegetation is beginning or underway. Ongoing wilding conifer control will be essential. In those locations where indigenous woody vegetation becomes established the resulting vegetation may, over many years, provide some resistance to invasion by wilding conifers. Being such a dry environment the canopy will be low and relatively open, and light levels on the forest floor may be relatively high. This may still provide suitable habitat for Douglas fir seedling establishment and growth.

Box 3 contains a summary about predicting ecological succession, while Box 4 contains a summary of models for vegetation succession in South Island drylands.

Box 3: Predicting ecological succession

There is a considerable amount of scientific literature on the theory of ecological succession in different environments. In New Zealand a number of studies have predicted ecological succession pathways for particular locations and/or for biological communities. A common approach for forest and other long-lived communities has been to study vegetation of different ages and determine the relative timing of transitions. A smaller number of studies have monitored changes at a site over many years. More recently computer modelling using field and other data has been used to predict pathways for ecological succession (e.g. Meurk & Hall 2006). These new techniques provide opportunities to consider future vegetation patterns with the inclusion of invasive species.

Usually only part of a terrestrial system (e.g. the vegetation, components of the above-ground fauna) is studied at one time. The links between above-ground and below ground communities and

processes are increasingly being recognised as affecting the rate and direction of community change in ecological succession (Van der Putten et al. 2009). Below ground interactions may contribute to the success of invasive species as those species may either be less sensitive to the soil biota (compared to native species) and /or they exhibit more positive soil feedbacks. For those introduced species that require specific mycorrhiza, rates of invasion into natural areas can be slowed if the required mycorrhiza is absent. This is discussed further in the context of Douglas fir in section 2.1.4.

Box 4: Models of ecological succession for South Island drylands

Walker et al. (2009a) proposed a model for current vegetation dynamics in the South Island drylands. This encompassed four broad states:

- State I –short stature grasslands of unpalatable native species with introduced components
- State II- introduced dominated grassland/herbfield including oversown grass species and pasture weeds such as *Hieracium* spp
- State III- mixed unpalatable native and introduced woody communities in a grassland matrix
- State IV- the relatively rare continuous canopy taller woody communities

They suggest that States I and II are unstable grassland communities and in the absence of woody vegetation control will shift to State III (shrub communities in a grassland matrix). Such woody establishment has been widespread with approximately 28% of undeveloped land in the New Zealand drylands now supporting (mostly mixed native and introduced) seral shrublands (Walker et al. 2009a).

Walker et al. (2009a) observed that while a decline in the use of fire as a management tool over the last 50 years may have promoted transitions from states I &II, to state III, periodic burning may favour an oscillating transition between fire-adapted introduced (e.g. gorse and broom) or native fire-tolerant (free-seeding kanuka and manuka) woody species and a state II introduced grass/herbfield. Harsh environmental conditions slow vegetation succession processes and the states in the model are neither stable nor necessarily discrete. In fertile grasslands the removal of grazing can lead to rapid increases in introduced grasses and herbs (Meurk et al. 1989) that potentially delay transitions to more woody states.

Where fire occurs only at natural low levels, where seed is available and the site is not too dry, Walker et al. (2009a) expected the state III mixed shrublands would shift towards state IV with more continuous woody vegetation. This would probably be slower at drier sites (Meurk & Hall 2006). Ledgard (2004c) suggested that tall introduced woody weed species might establish more readily at drier sites as they grew faster than the native species. Walker et al. (2009a) commented that no transitions from stage III to stage IV had been observed for drylands.

The state and threshold conceptual model developed by (Standish et al. 2009) for the restoration of abandoned agricultural lands for New Zealand indicated many possible vegetation states with the transitions between them largely dependent on land use history (fire and grazing), abiotic conditions and availability of native and introduced seeds. They predicted that where old-fields are poorly connected to remnant indigenous vegetation there would be a high probability that introduced species would establish. Six vegetation states were identified (indigenous climax, exotic alternate, indigenous seral, indigenous arrested state, exotic seral and exotic arrested state. For submontane Canterbury the "exotic alternate state" (to "indigenous climax state") was contorta pine and/or

Douglas fir.

4.3 Impacts on non-dryland ecosystems where the potential vegetation is forest

Indigenous forest is the potential land cover for most of New Zealand outside the drylands and below the natural treeline. Introduced conifers can act as a nurse crop, especially where there is adequate moisture (Brockerhoff et al. 2003). Where moisture is limiting it is more difficult to grow a replacement understory crop. Studies on the impacts of introduced conifers on succession processes have found that some exotic-dominated systems may return to native dominance in the longer term (Williams 1983). Conversely taller and long-lived introduced species such as Douglas fir and sycamore have been predicted to last for several centuries and would only be replaced by native conifers where abundant seed is available and disturbance minimal (Meurk & Hall 2006).

Meurk & Hall (2006) used the forest model LINKNZ (with field data) to simulate succession pathways with and without disturbance and introduced woody species. Two sites were used in Queenstown – 349m and 500m above sea level. After 400 years, the canopy of the lower altitude site (without introduced species or stand disturbance) would be stable with silver beech and Hall’s totara contributing 60-70% of the forest biomass. If disturbance and Douglas fir were to be introduced at year 200, the model showed a dramatic decrease in indigenous biomass, with introduced species compromising 65% of the biomass 200 years after introduction and 90% after 300 years. Without further disturbance Meurk & Hall (2006) predicted that the Douglas fir would gradually be replaced by indigenous beech and podocarp species.

At the higher elevation site, 200 years after the introduction of Douglas fir (in the absence of major disturbance) the model indicated that the Douglas fir would make up 65% of the total biomass. After 300 years it would be 80%. The impact on beech, especially silver beech, would be particularly severe. Meurk & Hall (2006) concluded that while further investigation was required, model simulations indicated that at higher elevations, Douglas fir has the potential to establish and spread in the montane beech biome. Such spread could significantly alter substantial areas of the high country and decrease biodiversity and natural character values across these landscapes (Meurk & Hall 2006).

4.4 Using seedling growth and tree removal experiments to learn about the impacts of introduced conifers

4.4.1 Seedling studies using introduced conifers

In a study that sought to identify factors that can help tussock grassland resist invasion by introduced conifers, Allen & Lee (1989) found that sparse low growing inter-tussock plants over bare soil or bryophytes favoured the establishment of the three introduced conifer species (*Pinus contorta, Pinus nigra* and *Larix decidua*). The three Otago sites, with relatively intact *Chionochloa rigida* tussock grassland, showed relatively little resistance to invasion from a nearby conifer seed source. Allen & Lee (1989) concluded that conifer establishment could be reduced by grassland

management that reduces the availability of microsites favoured by introduced conifers. Ways to do this include: increasing the density of tussock bases, encouraging a continuous tussock canopy and increasing the cover and density of inter-tussock vegetation. Seed sources also needed to be controlled.

Davis et al. (2011) compared the establishment of Douglas fir and Corsican pine seedlings under kanuka and manuka shrubland. Three seasons after seed was planted they found that Corsican pine survival was greatest in the open and decreased progressively as canopy cover increased. In contrast Douglas fir survival was greatest at the canopy edge. Douglas fir survival under dense canopy greatly exceeded that of Corsican pine. They concluded that Douglas fir could better establish in shady areas under woody vegetation, although they recommended further research to determine long-term survival under moderate and dense shade.

Unpublished trials described in Ledgard (2006b) found that seven years after sowing into different vegetation types, Douglas fir survival was best in shrubland, followed by grassland, then mountain beech forest canopy openings, and worst in intact beech forest. Cattaneo (2002) found that the light and shelter offered by widely spaced plants in open shrublands assisted Douglas fir establishment and that some Douglas fir seedlings were able to establish within shrubs with an average height of 05-1m.

Even though Douglas fir seedling survival is lower in native (beech) forests than for other vegetation types, Douglas fir is still the only common introduced conifer capable of invading canopy gaps in native forests because of its higher tolerance of shade (Ledgard 2006b). Where the canopy of mountain beech forest has thinned (because of old age or possibly an environmental stressor) that forest is more vulnerable to Douglas fir. In that situation Douglas fir saplings can grow faster than beech (Thomas Paul, pers. comm.). Once Douglas fir reaches the canopy it provides an ongoing seed source that could lead to eventual replacement of the mountain beech forest by Douglas fir in that location.

4.4.2 Introduced conifer removal studies

The primary purpose of wilding conifer control has been to remove the conifers. Attention has recently been given to the effect of the removal method on ecological processes. Paul & Ledgard (2008) evaluated the ecological effects of dead conifers that had been felled six years prior to the study and left on site in an area of short tussock grassland near Lake Coleridge in Canterbury. They found that in the area by the felled trees both native and introduced grass growth increased, taller native shrub (matagouri (*Discaria toumatou*) and tauhinu (*Ozothamnus leptophyllus*) growth increased, while the prostrate native shrubs characteristic of the open grassland were out-competed. Near the felled trees the prostrate introduced herb *Hieracium* was inhibited by the taller grasses. The number of native species was nearly three times higher in the open grassland than in the area by the felled pines. These changes can persist for 20 years (Paul & Ledgard 2009).

In the Central North Island Ledgard (2009b) found that where very large or dense conifers had been felled in monoao (*Dracophyllum subulatum*) frost- flats, the resident monoao and lichen (*Cladia* sp, *Cladonia* sp) died. The replacement vegetation was grasses and in some places *Hieracium* sp.

Ledgard (2009b) thought the nutrient flush resulting from the felling of conifers (Paul & Ledgard 2009) may be “toxic” to monoao (or its ericaceous mychorrhizae) which grows in nutrient-poor sites. Ledgard found introduced grasses dominating some areas around decaying conifers felled 20 years earlier.

Paul and Ledgard (2009) compared vegetation successions following four removal methods (felling and leaving on site, mulching, harvesting and stem poisoning) on several South Island sites. All, except the Marlborough Sounds sites, were at 900-1000m altitude. In those areas where the conifers had been felled and left on site there was an initial flush of growth, especially of grasses. After about ten years the number and cover of native species was less than for control areas, while the introduced species were unaffected. Mulching led to an initial removal of all plant cover, but on uneven ground and/or where there are low green braches mulching can leave the lower parts of live wilding conifers behind (unless the mulcher is powerful enough to cultivate upper soil levels). These still live plants can keep growing and rapidly reach coning age. Paul & Ledgard (2009) suggested mulching could be a useful method if an area was being converted to pasture. Otherwise the method can result in poor control of wilding conifers.

In those Marlborough Sounds locations where wilding stands of radiata pine had been harvested five years prior to the assessment, the dominant cover was radiata pine (50%), followed by gorse, then *Gahnia*. In contrast, where radiata wilding stands of the same age had been killed using stem poisoning and left standing virtually all the replacement living canopy was native species, especially mahoe (*Melicytus ramniflorus*) and *Coprosma lucida* and there was a good number of native species per plot.

The use of stem poisoning followed by leaving the conifer standing generally led to good native succession processes in the Marlborough Sounds. This area has good rainfall and abundant woody native seed sources. Native species were better able to grow in the lower light levels under a dead conifer than were the light-demanding introduced conifer seedlings. In contrast the high light levels that follow canopy harvest, along with the associated soil disturbance, favoured the growth of light-demanding introduced conifers and gorse. Paul and Ledgard (2009) observed that the growth of woody native vegetation under standing killed conifers in the lower altitude moist Marlborough Sounds sites would not necessarily occur in the drier high country. Trials have recently begun seeding and planting native species around felled and standing dead introduced conifers in the South Island high country (Nick Ledgard, pers. comm.).

4.5 Indigenous species

Where low stature vegetation is overwhelmed by wilding conifers, there may be local extinction of individual species. Populations of *Hebe armstrongii* in the Waimakariri Basin, and *Hebe cupressoides* throughout the high country are threatened with local extinction because of wilding conifers (Harding 2001). Native lizards and invertebrates of open communities can be threatened by wilding conifer spread. Examples include the Cromwell chafer beetle (*Prodontria lewisi*) in the Clutha Valley and the robust grasshopper (*Brachaspis robustus*) in the Mackenzie Basin (Harding 2001). Table 6 lists plant communities and species threatened with local extinction resulting from wilding conifer spread.

Wilding conifer induced changes to the vegetation can affect a number of indigenous species of fauna. For example, in the area covered by the Wakatipu Wilding Conifer Strategy (Day & Ledgard 2009), there are eight to ten species of lizard including four geckos and four to six skink species. Their habitats, (including rock outcrops, slab-schist areas, open grassland and shrubland) are vulnerable to invasion by wilding conifers. Wilding conifers can also displace berry-bearing shrubs that host a range of invertebrates. The invertebrates in the Wakatipu area include many host-specific species. Examples include geometrid moths and shield bugs found on *Hebe odora*, a bat-winged fly (found near streams in low to alpine meadows), flightless beetles (found in tussock grasslands and montane and sub-alpine herb fields) (Lucas & Head 1995).

Table 6: Plant communities and species threatened with local extinction by wilding conifer spread (modified from Harding 2001 with input from Lynne Huggins, Department of Conservation, Southland Conservancy)

Species or Community	Location and Area	Weed Species Present
Hebe armstrongii	Enys Reserve, Canterbury	larch, *Pinus* sp., broom, gorse, blackberry, *Hieracium pilosella*
Hebe cupressoides	Pukaki Scientific Reserve, Canterbury; Ferintosh Retirement Area, Canterbury; Lake Lyndon, Canterbury; Cave Stream Reserve, Canterbury	contorta pine, *Pinus nigra,* cotoneaster, *Nardus stricta*; larch, contorta pine, rowan, broom, and others; *Pinus* sp., sweet brier, herbaceous weeds; radiata pine?, broom, crack willow, blackberry, gorse and others
Hebe dilatata, H. annulata	Takitimu Mountains	Contorta pine, *Pinus mugo, P. patula*
Myosotis "Mossburn", Brachyscome aff. Humilis "Westdome", Carex uncifolia	Eyre Mountains	Douglas fir, alders, gorse, briar, rose, broom
Olearia "pomahaka", Ourisia spathulata	Blue Mountains	Gores, broom, pine species
Celmesia hookeri, Uncinia purpurata, Pimelia popelwelli	Mid Dome- Garvie Mountains	Contorta pine, *P. mugo,* gorse, broom
Uncinia strictissima	Shag Point Scientific Reserve, Otago	radiata pine, Douglas fir, macrocarpa, gorse, broom, cotoneaster
Leptinella nana and *Myosotis australis var. lytteltonensis*	Lyttelton Scenic Reserve, Canterbury	radiata pine, gorse, hawthorn, bone-seed, boxthorn and others
Carex inopinata	Kowhai Point Scenic Reserve, Marlborough	*Pinus* sp., broom, gorse, blackberry and others
Land snail *Powelliphanta*	Mid Dome- Garvie Mountains	Contorta pine, *P. mugo*, gorse,

Species or Community	Location and Area	Weed Species Present
spedeni		broom
Cromwell chafer beetle *(Prodontria lewisi)*	Cromwell Chafer Beetle Reserve, Otago	radiata pine, thyme, sweet brier, herbaceous weeds
Chafer beetle (*Prodontria sp.*)	Aldinga Conservation Area, Otago; Flat Top Hill Conservation Area, Otago	radiata pine, sweet brier, broom, thyme, and others; contorta pine, radiata pine, sweet brier, broom, gorse, and others
Un-named species of skink	Dunes at Big Bay and Martins Bay, Southland	radiata pine, macrocarpa, blue gum, tree lupin, broom
Southern rata (*Metrosideros umbellata*) forest and *Celmisia monroi* at southern limit	Mt Ararat Rata Reserve, Canterbury	radiata pine, nassella tussock (potential threat)
Tussockland and rockland communities on ultramafic rock	Red Hills (Richmond Range), Marlborough	contorta pine, radiata pine, Douglas fir, mountain pine, Corsican pine
Shrubland on ultramafic rock	Hackett (Richmond Range), Nelson	radiata pine?, contorta pine?
Bog pine (*Halocarpus bidwillii*) shrubland	Bendhu Scientific Reserve, Canterbury; Wilderness Scientific Reserve, Southland	contorta pine, elder, sweet brier, broom; radiata pine, Douglas fir, rowan, gorse, broom, heather
Tussockland, herbfield	Kirkliston Range, Canterbury	contorta pine, elder, sweet brier, broom
Tussockland and shrubland	Queenstown Hill, Otago	*Pinus* sp., sweet brier, broom

4.6 Below ground impacts (soil chemistry, biochemistry and biota)

Introduced conifers change soil chemistry, soil biochemistry and soil biota. Such changes were demonstrated in a paired catchment study in the Upper Waipori catchment, Otago (Glendu). Here one catchment remained in indigenous tussock (*Chionochloa rigida*) while a substantial proportion of the other was planted in radiata pine (in 1982).

Yeates & Sagar (1998) evaluated soil chemistry, biochemistry and biota changes at this site. They found that the conversion from tussock grassland to radiata forest led to a reduction in: soil pH, exchangeable calcium, magnesium, potassium and iron (thereby confirming earlier work by (Davis 1994). They postulated that soil acidification under the pines resulting from organic acids and resins released by decomposing needles may have led to a loss of these exchangeable ions.

Yeates & Sagar (1998) found lower levels of microbial biomass for carbon, nitrogen and phosphorus in the mineral soils under radiata pine, compared to tussocks. This was because the soil organic matter inputs to the mineral soil were lower under pines. The decline in soil organic matter input under radiata pine could be attributed partly to the effects of acidic soils and partly because radiata pine takes up more nitrogen and phosphorus compared to tussocks. In addition, acidic soils are associated with increased levels of biologically toxic cations such as Al^{3+} and Mn^{2+}, and changes in microbial composition and activity (Yeates et al. 1997). Yeates & Sagar (1998) observed that soil microbial biomass was central to the ecological functioning of soils, and that this responded relatively quickly to changes in land management/use.

Other soil biochemical changes due to radiata pine included a lower ratio of microbial carbon to total organic carbon, and a higher microbial carbon: phosphorus ratio (Yeates & Sagar 1998). The first change indicated a shift in the state of equilibrium of the soil subsystem; while the second indicated a slight decline in the quality of organic matter input to the soil resulting from the higher phosphorus uptake by radiata pine (compared to tussocks).

A number of the observed soil fauna differences between radiata pine and tussock grassland were associated with the soil differences. The abundance and biomass of native megascolecid earthworms were higher under tussock, although the largest earthworms were found under radiata pine suggesting a change in the composition of the earthworm fauna. There was significantly lower diversity and maturity, and greater dominance in the nematode fauna under radiata pine. It is thought that this reflected changes in nutrient cycling.

The introduced conifer species responsible for almost all wilding conifers have ectomycorrhizas (Davis 2008) where there is a mantle of fungi around the root surface and hypae penetrate spaces around the root cortical cells where most nutrient exchange takes place. Ectomycorrhizas enhance the uptake of mineral nutrients, especially phosphorus (Davis 2008). This is because some ectomycorrhizas can degrade plant litter to mobilise nitrogen and phosphorus directly so bypassing microbial mineralisation pathways. This is most significant in cooler environments where phosphorus and nitrogen are limited and is an important factor enabling wilding conifer species to establish and thrive in these locations (Davis 2008).

Dickie et al. (2010) found that the diversity of myrcorrhizal fungi associated with pines is much lower and was almost all non-native species (apart from a few native species with a cosmopolitan distribution. In comparison the mycorrhizal fungi associated with mountain beech (*Nothofagus solandri* var *cliffortioides)* is diverse and largely consists of endemic species. They observed that widespread invasion of *Pinus* into grasslands in New Zealand contrasts with the failure of mountain beech to spread back into areas that it had occupied prior to human arrival and that the fungal mutualists associated with *Pinus* may be a major reason for this. Some of these non-native fungi associated with *Pinus* are distributed by mammals including deer (Dickie et al 2010).

4.7 Pastoral farming and forestry

Wilding conifer spread affects both pastoral farming and forestry but in very different ways. Intensive pastoral farming is typically on the lower slopes and flatter areas. It is characterised by

top-dressed and over-sown pasture ("improved pasture") and relatively intensive stocking rates. Wilding conifers are not typically a problem, except possibly Corsican pine which is relatively unpalatable (Harris Consulting 2000). Beneke (1962) found that when grasslands with (relatively palatable) contorta pine seedlings were grazed at average densities of 0.6 sheep/ hectare, less than 2% of contorta pine seedlings survived.

Extensive pastoral farming in the High Country is based on indigenous tussock grasslands and other low stature indigenous vegetation. This vegetation may have been considerably modified by a variety of historical land management practices and invasion by introduced plant and animal species. Damaging land use practices may have included repeated fires and overstocking. Such practices reduce the resilience of the indigenous grasslands and can make them more vulnerable to woody (e.g. wilding conifers) and herb (e.g. *Hieracium*) invasions.

The "unimproved" grasslands tend to be managed using low levels of stocking. Once the wilding conifer seedlings become saplings and then trees, active control measures are required. This costs money and time which may be difficult for the landowner/ occupier to commercially justify given the marginal value of the land for grazing. This leads some landowners and occupiers to leave the wilding conifers, which then spread further. This spread can affect downwind areas of conservation, landscape and sometimes recreational value. While the original source of the wilding conifers may have been on-farm plantings (e.g. woodlots, shelterbelts), the source can also be another landowner or Crown legacy plantings.

Commercial forestry based on introduced conifers can also be affected by wilding conifers. The current owners of a forest may be required by a regional pest management strategy to remove spreading introduced conifer species (e.g. Karioi Forest in the Central North Island). The risk of wilding conifer spread means that forest owners may require land use consents for planting and may need to reduce the size of the intended planting area or not plant in some areas. There are guidelines available which can help foresters reduce the risk of wilding conifers (e.g. (Ledgard & Langer 1999)). These guidelines do note that foresters should be prepared to monitor and manage any wilding conifer spread.

Wilding conifers can limit future economic land uses. Once wilding conifers invade grassland areas in sufficient numbers, some options for future land use, such as pasture development, can become more expensive. Development for commercial forestry may become more complex as unwanted trees have to be removed before the desired species/ varieties can be established. Although some areas of wildings have been harvested for commercial gain, most wilding forests are not commercially viable, because they are the wrong species (e.g., contorta pine), are of poor form (open structure), or are sited in areas that are expensive to access and harvest (Forest Research Institute 1998). The availability of New Zealand units under the Emissions Trading Scheme (section 5.5) for the storage of carbon in trees is likely to affect the economics of different wilding conifer management regimes for some properties.

4.8 Water yields

Trees can affect the quantity of water in surface water-bodies in catchments with seasonal soil moisture deficits. The mechanisms for this are tree interception of rainwater, increased interception loss from wet leaves, higher evapotranspiration and sometimes the greater rooting depth that allows trees to obtain water from lower down the soil column. These characteristics mean that more rain is required to recharge soil moisture levels (especially after dry spells) before there is runoff.

In many catchments trees are helpful for reducing flood flows and reducing in-stream sedimentation and erosion processes. They can also be helpful for maintaining or enhancing water quality and aquatic habitats. The effects of trees on water quantity in surface waters are not so appreciated in catchments where there are long-term seasonal soil moisture deficits. In these latter catchments flows can be reduced to levels that adversely affect in-stream aquatic ecosystems and existing direct uses of the water (e.g. water supply, irrigation).

Data from a number of New Zealand catchment studies have showed that where pasture has been replaced by radiata pine forest, there was a reduction in annual surface water yields of 30-81% (Duncan 1996; Environment Canterbury 2011). The upper end of the range was observed in the dry South Island sites. Replacing pasture with pines would be likely to reduce water flows by between 34%- and 80%, with ephemeral streams staying drier for longer (Duncan 1996). Paired catchment trials in Canterbury showed similar effects on water yield from forested areas (Duncan 2000). Further research looking at commercial plantation forests containing plantings at different stages of development found that the overall effect on water yield of converting from short grassland to pine forest would lead to a 40% reduction in water yield rather than the 50% indicated by the paired catchment experiments (Duncan 2003). This is because not all stages of forest have the same evaporative demands.

Environment Canterbury (2011) considered that the vegetation changes most likely to affect water yield in Canterbury were: planting of forest over former pasture; spread of wilding trees from plantations; spread of weedy woody plants onto pasture; and reversion to indigenous scrub and forest. They did however emphasise that while a change in vegetation from short grass to tall vegetation would have an effect on low flows in any catchment, the relative size of this effect would vary depending on the hydrological characteristics of the catchment. As catchments in the lower foothills lack snow storage they can experience prolonged periods of extremely low flow because: normal or below-normal rainfall from December to April is generally exceeded by evapo-transpiration; and there is a lack of capacity for the underlying rocks and gravels to store winter and spring rainfall and runoff.

Canterbury catchments most sensitive to flow reduction as a result of a change from short to tall vegetation were those: where the river flow regime depends on rainfall (compared to snow, ice, wetlands, spring sources); in low rainfall areas (600-1200mm/yr) and where summer evaporation exceeds rainfall; that lack geology or terrain that stores water; and that experience extremely low flows in summer and autumn compared to their mean flows (Environment Canterbury 2011). This included some catchments of the foothills, coastal hill country, intermontane basins and Banks Peninsula. Environment Canterbury (2011) describes the catchments most sensitive to the effects of

vegetation on stream change (i.e. where there is a low ratio of low flow to mean flow) as "flow-sensitive" catchments. Here the ratio of low flow to mean flow is less than 20%.

Environment Canterbury (2011) observed that a number of well-controlled studies in New Zealand and overseas have recorded statistically significant flow changes when either less than 10% of the catchment was planted in forestry or the existing forest was harvested. Different parts of the catchment make different contributions to water flow. Mosley (1999) identified riparian zones, valley bottoms, hillside depressions as the areas of greatest water storage. Trees planted or spreading to these areas would have a disproportionate effect on stream flow because they can maintain high rates of transpiration for longer.

There has been a long debate over the extent to which fog interception can augment water yields from tussock grasslands catchments in east Otago uplands. Initially the debate focused on conflicting results from lysimeter based studies and more recently stable isotope analysis suggested fog and rain could contribute equally to stream discharge. Mark & Dickinson (2008) reported that a paired catchment study in the south-central South Island (Glendu) found that after 22 years, water yield reduction in the afforested catchment (radiata pine) was 41% compared to the catchment with tall tussock (*Chionochloa rigida*) cover. Lysimeter studies showed that a tall-tussock grassland at Glendu yielded a very high 64% of the available 1300mm/yr rainfall (Pearce et al. 1984). Mark and Dickinson (2008) considered that fog (via tussock plants) made an important contribution to this water yield.

Most recently Fahey et al. 2011 compared mean annual water yields with predicted water yields (using the WATYIELD model) for five catchments in east Otago uplands. Their hypothesis was that because the model makes no allowance for fog, any excess in measured water over predicted could be initially attributed to fog. Only two catchments showed any excess with one being within the margin of error and the other was 15%. They concluded that overall fog did not make a significant contribution to water yields and there was no evidence that fog added as much as rainfall to the water yield for the assessed catchments.

Mark and Dickinson (2008) argued that the high water yield ecosystem service provided by indigenous tall tussock grasslands with Dunedin deriving 60% of its water supply from upland tall tussock grassland catchments. Wilding conifer spread into these upland tall tussock grasslands would not be compatible with retaining the very high water yields over time. The Parliamentary Commissioner for the Environment (2009) suggested that uncontrolled spread of wilding conifers could reduce water input to the hydroelectric power schemes located in the Waitaki and Clutha catchments.

Increased tree cover may reduce the recharge of deep aquifers in some dry areas. For example the Tasman District Council has defined a Moutere Aquifer Recharge Area, where new forestry is permitted on no more than 20% of any land title. This was the outcome of an Environment Court case (Wratten vs Tasman District Council), which recognised that tall vegetation can intercept up to 50% of the rainfall in the area. The aim was to protect groundwater recharge to sustain a groundwater resource already allocated to existing users down-gradient (Richmond et al. 2004).

Despite a high level of site-to-site variability in the hydrological consequences of the development or removal of tall forest cover, an expert review of the New Zealand literature (Fahey et al. 2004) was able to reach some general conclusions. Forest development over 100% of small-medium sized catchments that were previously in pasture or tussock grassland may reduce annual water flows by up to 55%, and low flows by at least 20%, but the full effects may not be seen until canopy closure 5-10 years after planting. Reversion of pasture to other woody forms of vegetation such as bracken, gorse or manuka will also reduce yields, but not to the same extent. Forests on land previously in pasture or tussock grassland can also reduce flood peaks by a third to a half.

4.9 Landscape values

Landscape values are dependent on perception and preference. An individual's perception of a landscape depends on the biophysical attributes of the landscape, individual sensory acuity and a wide array of personal and cultural factors (Froude et al. 2010). Preference can be affected by a variety of factors including familiarity (although it is not always the familiar that is preferred), knowledge and understanding about what is indigenous (in the context of New Zealand landscapes), age and cultural factors (Froude et al. 2010). Perception in the context of wilding conifers is discussed further in section 14.

Landscape preference is personal. Haggerhall (2001) found a high degree of consensus in landscape preference within societies where there was a commonly-shared idealised image for a preferred landscape. Researchers have found that people in New Zealand have different preferences and perceptions (e.g. Hock et al. 2001, Fairweather & Swaffield 2002, Newtone et al. 2002). It seems that there are variations in how people perceive the impacts of wilding conifers (Day & Ledgard 2009).

Introduced conifer tree spread is seen by many as a major threat to the landscape values of treeless areas of the inland eastern South Island. Within Queenstown Lakes District wilding conifers threaten the integrity of the identified Outstanding Natural Landscapes (ONL) and possibly the Visual Amenity Landscapes (VAL) of the Wakatipu (Day & Ledgard 2009). The ONL and VAL as depicted in the district plan address sections 6(b) and 7(c) and (f) of the Resource Management Act, and follow from a 1999 Environment Court decision (Resource Management Act C180/99). In the Wakatipu area (and other parts of the High Country) there is widespread concern that spreading wilding conifers could so alter the basic characteristics of the local landscapes so that they become like those found in North America. On the other hand, some people prefer some level of introduced conifer trees in high country landscapes (Peter Weir, NZFOA, pers. comm.). An assessment of public opinion to simulated increases in introduced conifers in several central Otago landscapes found that beyond a relatively low level of cover introduced conifers were not favoured (Keith Briden, Department of Conservation, pers. comm.).

4.10 Tourism and recreation

The open treeless landscapes (with their low stature indigenous cover) of Queenstown Lakes District are important for the local tourism industry. While Day & Ledgard (2009) observe that visitors may respond in various ways to a introduced conifer dominated landscape (with some preferring the

introduced conifers), they considered that the spread of wilding conifers into the local landscapes would have too many negative effects, and these would be likely to outweigh any benefits associated with wilding conifers.

Tracks used for recreation in the Queenstown Lakes District would be affected by wilding conifer shading and the views of the lakes and mountains would be lost (Day & Ledgard 2009). Examples of tracks that could be affected include Ben Lomond, Queenstown Hill, Sawpit Gully and Seven Mile.

Another high-profile area where wilding conifers have an impact on tourism values is the hinterland surrounding Mount Cook National Park. Here, wilding conifers on private and Crown lands affect the vistas of the National Park from outside the Park. If the combined area of plantings and wildings in dry inland areas is such that the flows in rivers are reduced (section 4.8) this could adversely affect recreational activities that depend on those rivers (e.g. fishing).

4.11 Maori cultural impacts

Wilding conifers can affect cultural landscapes important for Maori. They can block access to cultural sites, make it difficult to show remnants of cultural sites (including trails, markers and reasons for place names) and adversely affect the sites themselves. By changing the landscape in this way wilding conifers can make it difficult to pass on traditions. As yet the impacts on Maori cultural landscapes have not been large but there is concern that once a tipping point is passed there could be significant impacts (Cathy Begley, Ngai Tahu, pers. comm.).

In flow sensitive catchments the impacts of planted and wilding conifers could lead to significant reductions in flows and water way health. This could have a variety of consequences for Maori.

4.12 Fire

Older dense stands of wilding conifers contain large amounts of dead relatively flammable material. During dry summers and times of strong wind a fire could spread a considerable distance during times when water scarcity may make effective fire-fighting difficult. Such a fire could threaten conservation values on public and private lands, tourism, managed forestry plantations and other production activities. It also noted that grasslands can burn readily although the burns are not as hot because of lower fuel levels.

The presence of wilding conifers within non-woody plant communities may mean that a wild fire would burn longer and hotter than it otherwise would have. Some introduced conifer species are adapted to regenerate after fire. In New Zealand the rapid invasion by introduced grasses after fire means that this regeneration is not usually seen in New Zealand (Nick Ledgard, pers. comm.). The ability of many introduced conifer species (and various other weed species such as gorse) to regenerate after fire, contrasts with woody native vegetation of the drier inland eastern South Island which is poorly adapted to fire (McGlone 2001).

5 Predicting risks of future spread

Unless introduced conifer spread from planted forests and existing wildings is effectively managed the extent of land affected by wilding conifers will increase. Areas most at risk are vulnerable lands downwind of planted and self-established areas of spread-prone introduced conifers. North & Ledgard (2005) prepared a regional-scale predictive GIS-based map of areas at risk of wilding spread from current stands for the Upper Waitaki catchment. The first step was to identify vulnerable areas (suitable for conifer establishment if there was future seed rain). The second step was to predict areas where seed rain is likely in future (areas within 1km of existing conifer areas). From this they calculated that 74,000ha (7.4% of the area) was potentially at risk as it was both within 1km of existing conifers and vulnerable to conifer establishment.

They conducted a more detailed evaluation of an area adjoining and south of Lake Ohau, using Environment Canterbury data on wilding conifers (more comprehensive than Land Cover Database 2) and information about which areas were intensively farmed (low risk of wilding conifers establishing). This evaluation also included manual estimation of the distance and direction of seed spread for each existing stand.

A later project by McNeil (2008) used GIS tools to apply the decision support system for identifying the risk of wilding conifer spread (DSSb) (Ledgard 2008) to the Lake Coleridge area of Canterbury. The project used the following datasets: digital elevation model; Land Cover Database 2 and the South Island wilding conifer database compiled in 2006 (North et al. 2007). An electronic version of the decision support system (DSSb) developed by Ledgard (2008) was used to assess the risk of wilding conifer establishment for each point in the landscape. This was tested on an 80km x60km section of South Island high country with the maps providing a good “first-order” representation of the risk of wilding conifer invasion. McNeil (2008) found areas where the computer assessment differed from expert assessment because the spatial databases used in the computer assessment were not detailed enough; the wilding conifer information was of variable quality (including inaccurate or missing species information); and the assumption of a single wind direction. He observed that it was very difficult to model wilding seed spread in a detailed way over a large area. While information on the seed sources could be improved, McNeill (2008) considered that it would be very difficult to accurately map grazing intensity because this can change significantly over the short term.

Another problem with predicting the likely future spread is that large wind events at a time when conifer stands have mature seed can mean that seed is dispersed well beyond the distance used in computer models. In addition these large wind events can be from wind directions that differ from the prevailing wind direction used in the models.

More recently Thomas Paul from Scion, Rotorua has tried to improve the quality of the South Island wilding conifers dataset described in North et al. (2007). This includes obtaining some recent regional council data (e.g. recent monitoring data from Environment Canterbury) and some from forestry companies. There is a lack of funding for collecting more updated information and there is no North Island dataset. Using this slightly improved South Island wilding conifer dataset, Thomas

Paul has used GIS tools to apply the decision support system for assessing the risk of wilding conifers establishing at a site (DSSb) (Ledgard 2008). This application differs from that of McNeill (2008) in that it uses a probability approach to test different assumptions. While more testing is required to define the probability curves, it is possible to determine minimum and maximum risk (Thomas Paul, Scion, pers. comm.).

The Wilding Conifer Management Group website (http://www.wildingconifers.org.nz) includes two versions of four different South Island 1:50,000 topographical map sheets. These versions show:

- Wilding conifer establishment risk because of the vegetation present on the site
- Wilding conifer spread risk from existing stands

Figure 11 shows the wilding conifer establishment risk based on the vegetation cover present on the site for one of those 1:50,000 map sheets.

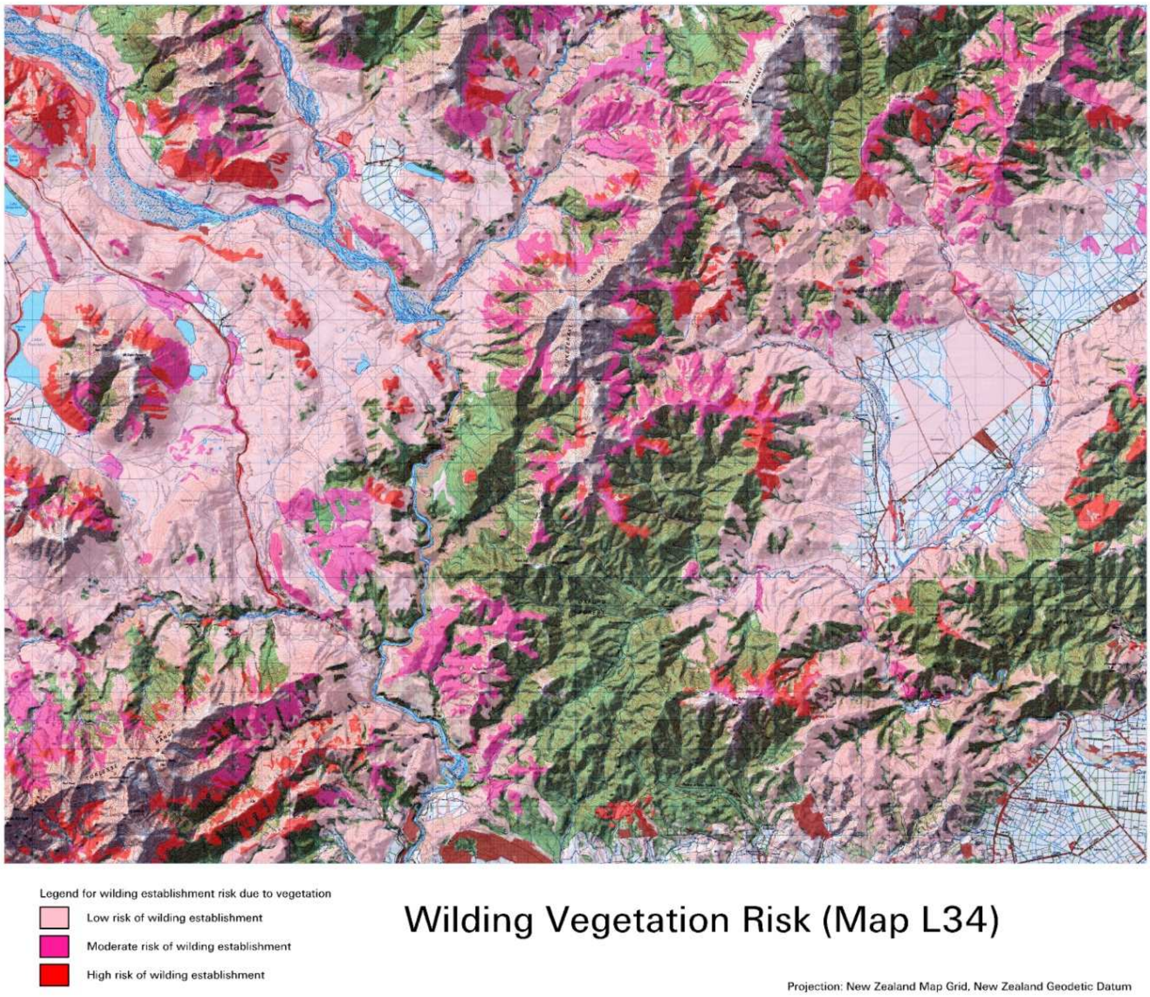

Figure 11: Vulnerability of the vegetation cover to wilding conifer establishment for the Upper Waimakariri, Canterbury (Source: Thomas Paul, Scion Rotorua)

Further work is required to improve the utility of the predictions and the geographic range of areas assessed. This will require: model refinement on smaller better datasets; improving the main

datasets used for wider application of the model; and scenario testing of alternatives. In some areas running the existing model with the existing datasets does not work well (e.g. Queenstown). In these areas local expert knowledge needs to be added into the model (Thomas Paul, Scion, pers. comm.).

Utility would also be improved by refinement of the decision support system used for assessing the risk of wilding conifers establishing at a site. Suggested refinements include:

- Adjusting species growth (spreading vigour) assessment to better reflect the risk of different species in different parts of New Zealand
- Reducing the weighting for species palatability as a low score only indicates a low risk if there are stock present
- Recognising that downwind land use can quickly change (e.g. from intensive grazing to no-grazing and this may even take place between the time of approval to the time of planting)
- Recognising that strong winds from unusual directions at certain times of year can lead to significant wilding conifer spread (e.g. wilding spread from Hanmer Forest to the Clarence catchment following Cyclone Giselle in 1968)
- Building in weightings that recognise the different contributions that various factors make to overall spread risk over time

A more detailed assessment of future wilding conifer spread has been undertaken for the Mt Dewar Station high country property (1796ha) in the Queenstown Basin. The station largely surrounds the Devils Creek Conservation Area. Up until the early 1970's the Station was virtually free of wilding conifer spread, but since then there has been exponential expansion and by December 2003 nearly one-third of the southern part of the property was affected by wilding conifers (Norton & Ledgard 2007). Without control it was predicted (using a conservative model of wilding spread) that all of the station would have a significant wilding conifer cover within 80 years, with Douglas fir dominating (Norton & Ledgard 2007). It was also predicted that adjacent areas would be affected with the Devils Creek Conservation Area likely to be fully occupied by wilding conifers within 40-60 years.

6 Relevant national legislation and policy

6.1 Biosecurity Act 1993

The Biosecurity Act 1993 is the primary statute for addressing wilding conifers, especially outside of lands administered by Crown agencies. In addition to being responsible for the administration of the Biosecurity Act, the Minister has responsibility (s8) for providing for the coordinated implementation of the Act. A summary of key relevant sections in the Act is in Appendix 5.

The national pest management strategy process has not yet been used for any plant species. Each regional council has prepared one or more (over time) regional pest management strategies. These strategies typically contain various provisions applying to a collection of plant and animal species. A number contain provisions applying to one (usually contorta pine) or sometimes more species of wilding conifer.

6.2 Ministry of Agriculture and Forestry Pest Management National Plan of Action

The Ministry of Agriculture and Forestry's Pest Management National Plan of Action (PMNPA) (Ministry of Agriculture and Forestry 2011) is a non-statutory document that seeks to make it easier for everyone involved in pest management in New Zealand to act collectively in the national interest. It sets out changes agreed by central and regional government to improve future pest management systems in New Zealand.

The PMNPA contains:

- Decision principles, outcomes sought and key characteristics (aspirations and intentions of policy makers) sought in pest management
- A set of improvements designed to provide an integrated response to current issues and opportunities. The implementation programme is staged over two, five and 25 years.

Relevant improvements identified in the Plan include:

1. Clear roles and accountabilities
    a. Refining the Biosecurity Act Part 5 purpose
    b. Providing for the Crown to meet its good neighbour obligations under RPMS once these align with national policy direction
    c. Establishing leadership functions for the Ministry of Agriculture and Forestry and regional councils
    d. Providing a mechanism to assign lead accountability for a complex pest management issue where roles are unclear
    e. Undertaking a comprehensive review of New Zealand pest management legislation
2. Improved and simplified processes
    a. Simplifying the processes for pest management strategy preparation and review and increasing strategy flexibility
    b. Providing legally binding national policy direction (under new Biosecurity Act provisions)

   c. Unified performance measurement framework for pest management in New Zealand (to measure outputs, outcomes and system performance)
3. Better and more accessible tools
   a. Developing integrated toolbox management
   b. Two-way capacity building for effective tangata whenua involvement
4. Acting collectively
   a. Promoting leadership for engagement and co-operation
   b. Partnerships
   c. Support for collective action in the community (including identifying ways to improve co-operation between funding streams and project implementation, and improve the effectiveness of funding support for individual and community pest management actions)
   d. Using a more collective approach national pest management programmes

One new mechanism (in 1 above) is for the Minister of Biosecurity to assign lead accountability for a complex pest management issue where roles are unclear. When a lead party has been assigned by the Minister that agency must make a decision about whether to take action. When making a decision about whether to assign accountability the Minister is to:

- Determine whether collective action could result in better outcomes than individuals acting alone
- Make a preliminary assessment of the preferred high-level objective for the pest management issue

The process for the Minister's role will be detailed in regulations made under the Biosecurity Act. The Minister's assignment of the lead party will bind all central and regional government agencies, but not private parties.

6.3 Biosecurity Law Reform Bill 256-2 (2010)

The Primary Production Select Committee under the 2008-2011 Parliament examined this Bill and recommended that it be passed with amendments. The reduced number of Parliament sitting days available (due to the Rugby World Cup) was one of the reasons that the Bill was not passed before the 2011 General Election. It has yet to be determined what priority the Bill will have in the new Parliament's agenda

The Bill makes some substantial changes to the Biosecurity Act 1993 and implements many of the matters set out in the Pest Management National Plan of Action (Ministry of Agriculture and Forestry 2011). Significant new provisions (from the perspective of wilding conifer management) include:

- The Minister may assign responsibility for an issue relating to a harmful organism or pathway (s55). Criteria to be considered when assigning responsibility and consultation processes are to be specified in regulations (s165)
- The Minister must make a national policy direction (which may be amended or revoked and replaced) (s56). The national policy direction may include directions on the contents and processes for making plans under the Act

- National pest management strategies are replaced by national pest management plans and can be for one or more organisms (s61). Provisions relating to the risk profile/ current status of organisms which can be addressed by such a plan appear to be less restrictive than for the current national pest management strategies
- Regional pest management strategies are replaced by regional pest management plans (s67-76)
- The Bill addresses national (s77-84) and regional pathway management plans, operational plans (s98)
- Management agencies are required to prepare annual operation plans (s98)
- After national policy is made, amended or replaced, national and regional pest management plans are to be assessed for consistency (s100AA)
- The Director-General may establish and maintain a biosecurity database for purposes of the Act (s142)

6.4 Other national biosecurity policies

The National Pest Plant Accord (New Zealand Government 2008) is an agreement between the Nursery and Garden Industry Association, regional councils and government departments with biosecurity responsibilities. Pest plants listed in the Accord have been determined to be unwanted organisms under the Biosecurity Act. This ensures that sections 52 and 53 of the Act (banning communication, release, distribution, sale and propagation) apply to these pest plants throughout New Zealand. Accordingly a pest plant does not have to be included within a specific regional pest management strategy for sections 52 and 53 of the Act to be enforced. The only conifer specifies listed in the Accord is contorta pine (*Pinus contorta*).

Another potentially relevant Ministry of Agriculture and Forestry programme is the National Interest Pests Response (NIPR). This aims to eradicate selected established pests from New Zealand. Pests are selected because of their potential to have a significant impact on New Zealand's economic, environmental and social/cultural values. There are eleven current NIPR programmes (http://www.biosecurity.govt.nz/pests/surv-mgmt/mgmt/prog/nipr accessed 17 June 2011): Salvinia (*Salvinia molesta*), water hyacinth (*Eichhomia crassipes*), Johnson grass (*Sorghum halepense*), cape tulip (*Moraea flaciccida*), Pyp grass (*Ehrharta villosa*), Phragmites (*Phragmite australis)*, hydrilla (*Hydrilla verticillata*), white bryony (*Bryonia cretica*), rainbow lorikeet (*Trichoglossus haematodus*), Manchurian wild rice (*Zizania latifolia*). While the goal is generally eradication, the goal for Manchurian wild rice provides for the containment of intransigent populations in Northland. Wilding conifers have been considered for this programme but because the programme goal is species eradication they were not considered to be suitable candidates (Sherman Smith Ministry of Agriculture and Forestry, pers. comm.)

6.5 Resource Management Act 1991

The purpose (s5) of the Resource Management Act is to promote the sustainable management of natural and physical resources. It provides the regulatory framework for the management of land, water, air and the coastal environment out to 12 nautical miles. The Act provides a hierarchy of planning instruments. At the national level there are national policy statements and national

environmental standards. Regional government prepares mandatory regional policy statements and regional coastal plans. Other regional plans are optional. Territorial authorities prepare mandatory district plans. Decisions on land use are primarily made at the district plan level although a regional policy statement can provide high-level guidance (e.g. identifying urban boundaries). Further information about the Resource Management Act is in Appendix 5.

In the context of wilding conifer management, district plans can play a useful role in determining and regulating future land use. District plans can address matters such as:

- Using the wilding tree risk calculator (refer section 5 for further comment on the wilding tree risk calculator) to determine high risk situations for forestry plantations and other tree planting using introduced conifer species;
- Restricting or prohibiting the planting of species known to have a high spread risk in certain locations
- Addressing potential wilding conifer spread risk, impacts and management as part of the assessment process for relevant resource-consent applications

Regional councils can (via regional plans) control land use for the following purposes: soil conservation; maintenance and enhancement of water quality and quantity and aquatic ecosystems; and the avoidance and mitigation of natural hazards (s30). In the context of land use the regional council role is narrower than the district's role as the regional focus is the effect of land use on water and aquatic ecosystems.

6.5.1 Proposed National Environmental Standard for Plantation Forestry

The Ministry for the Environment has been preparing a National Environmental Standard (NES) for Plantation Forestry under the Resource Management Act 1991. Consultation and NES refinement processes are well advanced. A further (and non-statutory) round of submissions closed in mid 2011.

The wilding tree risk calculator (Appendix 4) has been included as an appendix to the proposed NES. It is to be used for determining the activity status for new afforestation (planting on land not previously used for plantation forestry). Where the wilding tree risk (assessed using the tree risk calculator) is equal to or less than 11 then afforestation would have permitted activity status. For situations where the scores are between 12 and 16 the activity status is restricted discretionary. In those situations where the score is greater than 16 the activity status is prohibited.

Under the NES the wilding tree risk calculator is not used for assessing replanting after harvesting. This is because of land existing use rights where the effects of the use are similar in character, intensity and scale (s10, Resource Management Act). However, where a different species with a higher risk profile is used for replanting this may lead to a higher risk of wilding conifer spread and so the effects would be different. It could possibly be argued that if "downwind" vegetation cover has a higher risk of wilding conifer establishment the effects would also be different. This would be administratively complex. It should be noted that the wilding tree risk calculator was developed for

the eastern South Island and unless it is made more complex does not readily translate to the rest of New Zealand (Nick Ledgard, pers. comm.). Further comments on the calculator are in section 5.

Table 1 in the NES lists the following environmental outcomes for biosecurity:

- Reduce the likelihood of wilding trees establishing at undesirable sites, and reduce the risk of wilding tree spread from any site
- Prevent further wildling tree spread so that wilding control is not required
- Where infestations do occur, maintain effective control activities at those sites until dispersed seed is no longer viable

These are relatively optimistic outcomes. The degree to which the first bullet point can be met will in part depend on the types of conditions set on higher risk proposals by local authorities. As the wilding tree risk calculator is only used for new planting the second bullet point could only be partly addressed. The NES does not specifically address the control of wilding conifer infestations originating from planted forests. This aspect could be addressed by local authorities setting appropriate conditions on new proposals requiring a resource consent. Local authorities are likely to be variable in the conditions they set.

6.6 Climate Change Response Act 2002

The first purpose of this Act is to enable New Zealand to meet its international obligations under: the United Nations Framework Convention on Climate Change dated 9 May 1992 (the Convention); and the Protocol to the Convention dated 11 December 1997; and subsequent amendments to both. The second purpose is to provide for the implementation, operation and administration of a New Zealand greenhouse gas emissions trading scheme.

Owners of post 1989 forest, holders of forest rights or licences, or Crown conservation contracts may voluntarily participate in the Emissions Trading Scheme by registering post-1989 forest land. Applications to be registered as a participant (s 188) must define the carbon-accounting area for which the applicant wishes to be a participant and submit a declaration that states that any action since 1 January 2008 complies with: the Resource Management Act and any plan under that Act, the Forest Act and a pest management strategy prepared under the Biosecurity Act.

Owners of pre-1990 forest land are mandatory participants in the ETS if they deforest more than 2 ha of pre-1990 forest land that is not exempt, in each five-year period from 1 Jan 2008. Section 179 provides further detail (beyond that in the interpretation) as to what constitutes deforestation.

The allocation for pre-1990 forest land is one of 18, 39 or 60 New Zealand units per hectare of eligible land depending on land ownership and timing of that (s72). Where a landowner had less than 50ha of pre-1990 forest land at 1 September 2007 and they have not been allocated units, then that landowner can apply for the land to be exempt land (s183).

An exemption process is available for tree weeds that exist on, or have been cleared since 1 January 2008 from, pre-1990 forest land and where no units have been allocated (s184). Exemptions are advertised periodically and are by application. Once approval has been given the landowner has until the end of the commitment period (or 5-year period) to clear the tree weeds. Tree weeds are

defined in regulations to the Act or in a pest management strategy prepared under the Biosecurity Act. If pre-1990 forest land is deforested without an exemption owners are mandatory participants in the Emissions Trading Scheme and face liabilities for their emissions.

ETS participants must notify the Chief Executive and open a holding account to surrender and repay units or to receive units (s61), and calculate emissions and removals (s62). The relevant activities are:

- deforesting (defined in interpretation and s179) of pre 1990 forest land (excluding exempt land) if the land deforested is more than 2ha in the five year period after 1 January 2008 or any five year period after that (Schedule 3); or
- forest removal activities for post 1989 forest (with exclusions already mentioned) (Schedule 4).

Wilding conifers can be on pre 1990 and post 1989 forest land. The pre-1990 tree weed exemption process has removed a potential liability for landowners/agencies/organisations who deforest pre-1990 forest land as a result of clearing wilding conifers. There is no prohibition on landowners registering areas of wilding conifers under the Emissions Trading Scheme, as long as this is not contrary to provisions in Resource Management Act plans or a pest management strategy prepared under the Biosecurity Act. This option is already being used by some landowners. In at least one case (Pukaki Downs) the funds earned from this have been used to purchase equipment to be used to remove other areas of wilding conifers (Elaine Curin, pers. comm.). The converse is that some landowners who may have been prepared to remove wilding conifers (especially if resources had been available) are or may register their wilding conifer forest in the Emissions Trading Scheme. Once registered, a landowner will have to repay any carbon credits claimed if subsequent clearance of the wilding conifer forest results in deforestation (i.e. it was not replanted in another tree species). This penalty would act as a disincentive to the future removal of that wilding conifer forest. There is a significant risk that registered wilding conifer forests may provide ongoing sources of seed that infest lands owned or managed by others.

6.6.1 Climate Change Regulations

The Climate Change (pre-1990 forest land allocation plan) Order 2010 (SR 2010/190) contains the allocation plan for New Zealand units for pre-1990 forest land. This provides additional detail to that in the Act for the allocation of units (in which circumstances the allocation is 18, 39 or 60 units per hectare).

The Climate Change (Forestry Sector) Amendment Regulations 2008 (SR2008/355) as at 1 October 2010 after the incorporation of the Climate Change (Forestry Sector) Amendment Regulations 2010 (SR 2010/183) addresses:

- information requirements, including geospatial mapping requirements
- methods for calculating emissions from deforestation and carbon stock changes over time
- tables for calculating carbon stock per hectare for pre 1990 (Schedule 4) and post 1989 (Schedule 6) forest land
- details for the tree weeds exemption process (s23-28), including information requirements for applications

- the list of forest weed species (Schedule 7) that are considered to be tree weeds for the purpose of the Act (in addition to any other species that are in a relevant pest management strategy prepared under the Biosecurity Act)

The Schedule 7 list of tree weeds includes the following conifers: cedar (2 species), Douglas fir, larch (2 species), Lawson's and Leyland cypress; pines (12 species), redwood and Sierra redwood and western red cedar. This list includes all the most troublesome spreading introduced conifer species. Macrocarpa, which has been recorded as a local problem in a few situations on conservation land, is not included.

6.7 Forests Act 1949

Part 3B sets up the framework for a process whereby landowners (including the Crown) can access the value of carbon sequestration created by the Kyoto Protocol. Under section 67Z a forest sink covenant gives a landowner rights to receive units based on carbon sequestration. There are exceptions to control timber harvesting. The landowner has obligations to the Crown to meet liabilities resulting from the loss of carbon from the sink. The covenant is in perpetuity. A forest sink covenant is registered under the Land Transfer Act (s67ZD).

6.7.1 Forests (Permanent Forest Sink) Regulations 2007

Under s3 (Interpretation) an eligible forest is larger than 1ha and >30% cover. The trees are to be at least 5m tall at maturity. Non-eligible areas are:

- Shelterbelts less than 30m wide
- Areas of forest less than 30m wide unless they are contiguous with other eligible forest

Also under s3, a forest sink is defined as eligible forest growing on, or will be grown as a result of active establishment, Kyoto-compliant land. Kyoto-compliant land is that not covered by eligible forest at midnight on 31 December 1989.

Under section 4 of the Regulations landowners can apply to the Minister to enter a forest sink covenant (and submit a suitable forest sink plan). Subject to the covenant, harvesting must be consistent with "approved harvesting practices (s7) and continuous cover can only be removed for salvage or public works purposes (s8). Landowners can receive units for the net increase in carbon stock for the first and subsequent commitment periods.

The Regulations do not exclude land with tree weed species (including wilding conifers) from being registered in a forest sink covenant as long as the criteria for "eligible forest" are met. There are no requirements to be consistent with a pest management strategy prepared under the Biosecurity Act or with the Resource Management Act or plans prepared under that Act. This would allow an area of, for example, contorta pine to be registered in perpetuity irrespective of present or future pest management strategy provisions.

6.8 Statutes administered by Land Information New Zealand

The Crown Pastoral Land Act 1998 establishes a system for reviewing the tenure of Crown land held under certain perpetual leases and provides for the administration of Crown pastoral land. A pastoral lease (s4) provides for exclusive right of pasturage, perpetual right of renewal for 33 years, no right to the soil and no right to fee simple. An occupation licence (s12) is similar except that there is no right of renewal. A lessee or licensee is not to burn any vegetation (excluding timber); nor clear or fell bush or scrub; nor plant any trees; without the approval of the Commissioner of Lands (s15-16).

The objects of the tenure review process (Part 2 of the Act) include (s24):

a. Promote ecologically sustainable management of reviewable land
b. Subject to (a) enable reviewable land that is capable of economic use to be freed from management constraints
c. Enable the protection of significant inherent values of reviewable land by the creation of protective mechanisms or preferably by the restoration of the land to full Crown ownership and control

Reviews can include adjacent unused Crown land or adjacent conservation areas and reserves with consent of the Minister of Conservation. No land can remain or transfer to Crown control as a conservation area/reserve if it is subject to a concession that does not have consent of the Minister of Conservation (s48). Matters for the Minister to address in making this type of decision are specified.

Under section 99 of the Land Act 1948, leases and licenses are to be properly farmed with "no waste", land to be kept free from wild animals, land to be clear of weeds, drains and watercourses to be kept open. There is to be no felling, removal, sale of any timber, tree or bush that is growing, standing or lying. Destruction or burning is to be prevented unless the Commissioner approves. The exceptions are use of timber for any agricultural, pastoral, household, roadmaking, or building purpose or if the tree was planted by the lessee (s100). The land is to be kept clear of all noxious weeds and the provisions of the Noxious Plant Act 1978 are to be complied with. The Land Settlement Board is the sole judge of whether a lessee or licensee has complied with the required conditions in both the lease/license and the Act (s105). Some pastoral lease properties contain a high level of wilding conifers (Parliamentary Commissioner for the Environment 2009).

The tenure review process has led to an increase in conservation land in some of the areas of the South Island that are particularly vulnerable to wilding conifer invasion. This land is not grazed by farm animals as that is not generally consistent with biodiversity protection objectives. Some of the land recently transferred to Department of Conservation management, may, because of past management, contain an open vegetation structure that is more vulnerable to wilding conifer invasion. It may also contain wilding conifers at the time of transfer. Tenure review also leads to the intensification of areas with economic potential. This may lead to additional introduced conifer plantations being established close to vulnerable protected areas.

LINZ also administers unalienated lands of the Crown under other statutes. This includes some lake beds and most river beds. LINZ is responsible for weed (including wilding conifer) management on these areas.

6.9 Statutes managed by the Department of Conservation

The primary statute administered by the Department of Conservation is the Conservation Act 1987. Many of the South Island High Country areas managed by the Department are administered directly under this statute. Other protected areas affected or potentially affected by wilding conifers are managed in accordance with one of the following statutes: National Parks Act 1980, Reserves Act 1977 and Wildlife Act 1953. Protected areas are to be managed to protect their natural (indigenous) values and details vary for different types of protected area. Introduced species, including wilding conifers, are not consistent with that goal, except in s.19(b) Scenic Reserves. More detailed management objectives are contained in Department of Conservation General Policy, conservation management strategies and specific operational plans.

7 Relevant regional and district policy

7.3.1 Regional pest management strategies

Appendix 6 contains a table summary of the key provisions relating to wilding conifer species in regional pest management strategies (RPMS). Only councils involved with either or both of the New Zealand Wilding Conifer Working Group and the Central North Island Contorta Co-ordinating Committee are included in this summary.

This Table shows that there is considerable variation between regions, reflecting different patterns of present occurrence, varying potential risk profiles, and different political contexts. In most cases the focus is on contorta pine although Southland also includes mountain pine. Several regional pest management strategies contain general provisions relating to wilding conifers (e.g. Canterbury and Bay of Plenty Regional Councils).

Most strategies reviewed (excluding Canterbury) have specific rules for contorta pine control and containment. The RPMS for Horizons contains a zero density objective for contorta pine within the Volcanic Plateau Control Area. In its most recent RPMS, Horizons has moved to directly control contorta pine on private rateable land within the Control Area. Other parties (Department of Conservation, New Zealand Defence Force, Karioi Forest and roading authorities) undertake control on lands they manage within the Control Area.

The Canterbury Regional Council RPMS focuses on wilding conifer control in high value natural areas, with an emphasis on facilitating landowner and community control. Canterbury Regional Council provides support services for the Waimakariri Ecological and Landscape Restoration Alliance (WELRA). The Southland Regional Council RPMS requires land occupiers to clear all contorta and mountain pine on land they occupy. The Council also participates in the community trust programme to control wilding conifers on Mid Dome. Further information on this Trust is in Appendix 11.5. Otago Regional Council's RPMS requires land occupiers to remove/ strictly contain contorta pine in clearance and containment areas respectively.

Other than contorta pine (and mountain pine in Southland) RPMS rules do not specifically address introduced conifer species that pose potential risks to ecological, production, water/aquatic habitat and landscape values in some locations. Reasons for this include the limitations associated with the required cost-benefit analysis (under the Biosecurity Act) and opposition from some.

7.3.2 RMA district plan provisions

District plans vary in how they address activities that could affect the distribution and density of wilding conifers. Appendix 7 contains a summary of relevant provisions from a selection of South Island District Plans for areas affected by wilding conifers. The most comprehensive provisions were found in the Queenstown Lakes District Plan where in the Rural Zone the planting of wilding conifer species most likely to spread (contorta pine, Scot's pine, Douglas fir, European larch, Corsican pine, radiata pine) is prohibited. Also in this zone forestry is a discretionary activity and tree planting is a

restricted discretionary activity. There is to be no forestry or planting of exotic tree species above 1070m altitude. Matters that Council is to address in its decision include the potential for wilding conifer spread and potential impacts of that. In the Open Space/Landscape Protection Zone, forestry is a non-complying activity, except for the removal of wilding trees. In this zone the planting of any species with the potential to spread is a prohibited activity. The Council is also actively involved in wilding conifer control. It sponsors the Wakatipu Wilding Conifer Control Group (http://www.qldc.govt.nz/wilding_trees) with staff time and annual financial support of $120,000 per year (Appendix 11.6).

Several councils prohibit the growing of some wilding conifer species in all or parts of the rural environment. In Southland the planting of contorta pine and mountain pine is prohibited in the Mountain Resource Area. The planting of contorta pine is prohibited in rural Central Otago and the planting of Scots pine and mountain pine is a non-complying activity.

Clutha District does not use rules to restrict the planting of introduced conifers that may spread. Instead it prefers to encourage prospective planters to consider potential wilding conifer spread.

7.3.3 Resource Management Act regional plan provisions

Compared to local authorities, the role of regional councils in regulating land use is more restricted. Under section 30(1)(c) of the Resource Management Act regional councils can control the use of land for the purposes of: soil conservation; maintenance and enhancement of water quality and aquatic ecosystems; maintenance of water quantity; and the avoidance and mitigation of natural hazards. Regional councils also have the function of developing and implementing policies and methods for the maintenance of indigenous biodiversity (s30(1)(ga)).

Regional councils can include policies and methods in regional policy statements and regional plans that protect indigenous biodiversity through preventing and controlling wilding conifers. Water regional plans could be used to regulate introduced conifers and other tree planting in locations where it is considered that they could adversely affect water quantity in surface waters.

An example of this can be found in the operative natural resources plan for Canterbury (Environment Canterbury 2011). Under policy WQN5 the use of land for plantation forestry is controlled in the flow-sensitive catchments (listed in Schedule WQ15) to achieve objective WQN2. This objective seeks to protect the flow requirements for instream values and the supply of water to existing permits in all (defined and specified) flow-sensitive catchments. Under this objective any changes in land cover from short to tall vegetation should not significantly: increase the frequency, duration or severity of times when the river falls below the set flow regime or the flow needed to protect in-stream values; reduce availability for any community, domestic or stock water supply; or reliability of supply to existing permit-holders.

Policy WQN6 encourages landholders within the low-flow production areas of the flow sensitive catchments to maintain areas of short or open vegetation cover to reduce any adverse effects of their land use on water yield. Recommended management practices to achieve this included: using grazing regimes that discouraged the establishment or growth of woody vegetation, removal of

wilding trees; and using wide-spaced plantings of appropriate tree species on slopes prone to deep-seated erosion where this can adequately stabilise the slopes.

Under rule WQ27 the replanting of plantation forest in flow-sensitive catchments is a restricted discretionary activity where it exceeds that area planted and/or is in a different location to that which existed on 1 November 2010 or was authorised under Rule WQN28. In assessing applications, the matters that Council can address include: impacts on the water allocation of the catchment, effects on flows, flow regimes, instream values, authorised takes, benefits of forestry, effects on flood-carrying capacity, and effects on flows of any wilding spread.

Under rule WQN28 the planting of new areas of plantation forest within any flow-sensitive catchment is a controlled activity, if it and all other new areas of planting in the same flow-sensitive catchment since 1 November 2010 will not cumulatively cause more than a 5% reduction in the seven day mean annual low flow, and/or more than a 10% reduction in the mean flow. It is a discretionary activity where the previous two conditions are not met.

8 Wilding conifer management approaches and techniques

8.1 Determining management priorities

There have been various evaluations of the benefits/priorities of specific wilding conifer policies or control programmes. A “cost-utility” analysis (Stephens 2004) of a range of conservation projects in the Department of Conservation administrative units of Twizel (South Island) and Maniapoto (North Island) included wilding conifer control projects in different ecological contexts. A methodology summary is in Box 5.

In Twizel, the potentially severe impacts of wilding conifers and the large proportion of the area that could potentially be invaded, led to the most cost-effective project in the area being a comprehensive wilding conifer control project. Reasons for this project being most cost-effective are described in general terms in Box 5. This hypothetical project was defined to be that within seven years all wilding conifers on Department-administered land would be controlled, and the Department would work with the Regional Council and landowners to include wilding conifers in the RPMS with the expectation that landowners and leaseholders would control wilding conifers on their own/leased lands. The second most cost-effective project was the control of wilding conifers only on Department of Conservation administered lands within seven years. The project that was underway at the time of the analysis was a much lower level of wilding conifer control (outcome expected in 50 years). This was not particularly cost-effective compared to other conservation projects.

The cost-utility analysis for the Maniapoto Area showed that potential wilding conifer projects for small high-value sites were highly cost-effective. In contrast to Twizel, weed-led wilding conifer control was not a cost-effective conservation activity because the wilding conifers were considered to largely be a successional species except for wetlands and some frost hollows.

Box 5: Methodology used for a cost-utility analysis of conservation projects

Stephens (2004) assessed the value of various conservation actions to “*biodiversity integrity*” per unit cost. The conservation actions included several strategies for wilding conifer management. Biodiversity integrity was described in terms of native biodiversity condition (composition, structure and state of natural processes) relative to reference conditions, and pattern (spatial arrangement of ecological variation in the landscape). Stephens (2004) uses the following pressures as a surrogate for condition assessment: biota removal; physico-chemical removal; competition; consumption; and fragmentation.

Biodiversity integrity was assessed using an index that combined site area, the pressure on it, its distinctiveness, and its contribution to representativeness. The “difference made” is the change that would be made to this index by the successful implementation of the project. The “project merit” is the “difference made” weighted for time and risk; while the relative value of a conservation project is the project merit divided by the nett present value of the cost of doing the project.

In the Twizel area, where wilding conifers were rapidly invading grasslands, shrublands, riverbeds, wetlands and alpine communities, Stephens (2004) considered that much of the area was potentially vulnerable to invasion. Assumptions made: only limited areas were not vulnerable (including land >2000m altitude and developed pastoral land); and above 1600m there would be only 30% wilding conifer cover. It was recognised that this was a worst case scenario based on contorta pine and that no account was taken of limitations in the most drought-prone parts of the McKenzie Basin.

In contrast to the site-based focus of most Department of Conservation weed management projects, (Stephens 2004) considered that wilding conifer control was "species –led" because conifers could spread into extensive areas and become an intractable problem. Consequently introduced conifers are controlled anywhere on Department of Conservation land from which they could spread, rather than just on sites that affect biodiversity values. Two management strategies were assessed:

(a) Control (to <1% cover) on all land administered by the Department
(b) Option (a) plus control by landowners and leaseholders of all conifers that are not in specified plantations or shelterbelts

In the Maniapoto Area, wilding conifers were widespread particularly in highly disturbed areas that are now regenerating shrublands. Stephens (2004) considered that in most areas the wilding conifers seemed to be successional species that would not persist without further disturbance. The exception was the wetland areas and some frost hollows. (Stephens 2004) commented that spread seemed to be slow with some increase in cover resulting from small-scale disturbances. In Maniapoto cost-utility analysis wilding conifers management was site-led. Trees would be removed if they were having significant adverse biodiversity and landscape effects at the site.

8.2 Prevention

Ledgard & Langer (1999) emphasise that prevention is the best form of control. They state that the predictability and visibility of wilding conifers means that it is more practical to manage their spread than that of many other pest plants. Predictable elements include: direction of spread (mostly down-wind); age of seed production (usually 8-12 years); high risk take-off sites (summits, ridges and slopes exposed to prevailing winds); and vulnerable sites (Ecologically valuable sites with low stature vegetation, light vegetation cover and light/no regular grazing). Wilding conifers are usually very visible well before coning begins. Another factor that assists with prevention is that the soil seedbank for introduced conifers has a relatively short life-span (up to five years), in comparison to weed species such as gorse (40 or more years)

Ledgard & Langer (1999) provide guidelines on how to plant introduced conifer species to minimise their risk of spread. Further details are provided for Douglas fir in Ledgard (2006b). Key points include: avoiding planting on take-off sites (ridges and upper slopes exposed to especially the prevailing wind); avoiding creating a long axis of planting perpendicular to the prevailing wind; avoiding planting upwind of vulnerable vegetation; and using less spread-prone species around the margins of the planted area. The planting of the introduced conifer species that poses the greatest spread risk, contorta pine, is not now allowed in many high risk areas (sections 7.1.1, 7.1.2). If, properly implemented the guidelines should reduce the risk of spread from newly planted areas.

Even so there will still be a requirement to manage the spread that does occur. In addition there are large areas of existing plantings- some of which pose a significant and ongoing risk of spread. Many of the existing wilding conifer spread areas are themselves current or potential sources for further wilding conifers spread.

8.3 Eradication

Ledgard (2009a) outline the suite of methods ("toolbox") that can be used for removing wilding conifers. He identifies which types of methods are most suitable for small, medium and large trees and when the trees are scattered or close together. For each type of method Ledgard identifies the actual tools required, whether the method is suitable for volunteers or contractors, safety issues, auditing, 2008 costs, problems, other comments and recommendations. Types of methods addressed include: burning, grazing (sheep); fertilising, hand-pulling, hand tools, ring-barking, chainsaw, scrub-bar, mulching, digger, foliar spray, cut-stump poisoning, stem poison, bark application of chemical and soil uptake of chemical.

Control operations can be ground or aerial based or a mixture of the two. Ground based operations are the most common and can use contractors or volunteers depending on the specific methods being used. Where only physical control methods are used all green foliage must be removed or else the tree can resprout and be more difficult to remove the second time.

Where the wilding conifers are remote or ground access is poor, helicopters are often used. They can be very cost-effective when wilding conifers are present in low densities across a large area. Helicopter skid operations move workers from site to site as necessary. An alternative in steep locations or where wilding conifers are difficult to find and access, is for an operator to be moved from tree to tree while attached to a strop attached under a helicopter. The latter requires highly trained personal and there are strict safety requirements. Another approach for accessing wilding conifers on bluffs is to use trained abseilers (e.g. Ministry of Defence land at Waiouru, Appendix 11.3.)

Matters to consider when selecting methods for a particular control/eradication operation include: the characteristics of the conifers being controlled (size, density, accessibility), characteristics of the site (topography, vegetation, current and intended land use, ground surface) and values of the site and its environs without introduced conifers (e.g. ecological, recreation, visual), overall control and long-term management strategy for the broader area, and finance available. A message that is frequently conveyed in relation to wilding conifer management is a "stitch in time saves 9" (SITS), e.g. Ledgard (2009a).

The Department of Conservation has large areas of wilding conifers to eradicate and with reducing budgets undertakes considerable operational research to develop and refine cost-effective methods of control. In the South Island it has played a lead role in refining control/eradication methods and disseminating the results to others via workshops (Keith Briden, Department of Conservation, pers. comm.) One recent area of methodology research by the Department of Conservation and Scion has been to determine better mixes and doses of chemicals for aerial application (for both individual trees (spot spray) and blanket spraying) for killing contorta pine, mountain pine and Douglas fir.

Gous et al. (2010) found that the most effective treatment contained two systemic herbicides triclopyr and picloram which caused a minimum of 98% damage for the three tested species.

A key component affecting the success of any eradication/control programme is follow-up after the initial eradication work. While it is important for the initial control to be as thorough as possible, it is highly likely that some (often small) plants will be left behind and that seeds in the soil will germinate. If long-term systematic follow-up of the initial control operations is omitted, it is likely that introduced conifers will regenerate/ recolonise the site. Woods (2004) commented that the timing of follow-up was important. If it was too regular this would impose unnecessary costs. Left too long and the regeneration could have enough time to set seed and spread still further.

There are a number of examples where sporadic funding has led to inadequate follow-up after initial control. As a result the problem has returned in a few years. For example, a pine infestation at Kirkliston in the southern Canterbury high country was nearly under control in 1990. The Department of Conservation lost funding for that control in the early 1990's and by 2009 the area was in the same state as before control work began (Parliamentary Commissioner for the Environment 2009). The wilding conifers on Kirkliston have now been removed (Nick Ledgard, pers. comm.).

8.4 Containment

A strategy of containment can be the most appropriate approach for large inaccessible plantings of spreading introduced conifers, particularly where there are boundaries that can be easily defended. There are some large areas that were typically planted for erosion-control purposes in the 1950's - 1980's using spread-prone species. Today's management agencies (typically the Department of Conservation) do not have the funding to remove these planting. In some cases removal may create other land management costs/problems.

The Branch and Leatham catchments in South Marlborough provide an example of an area where containment is an appropriate strategy. These two catchments have received more erosion control plantings than any other New Zealand catchment. The first plantings (by the New Zealand Forest Service) were in 1963. Nearly 500,000 trees were planted by 1973 and another 1,300,000 trees were planted up to 1986. A larger area contains introduced conifers established by aerial seeding (using 1.5 million tonnes of conifer seed) (Ledgard 2004c). A variety of species were planted, with the most vigorously spreading species being contorta pine, the mountain pines and Douglas fir. Today the area affected is large and there has been relatively little control. The primary aim for management (by the Department of Conservation) is to contain the introduced conifers within the Branch and Leatham Catchments (Ledgard 2004c).

8.5 Biological control

Biological control has been suggested as a way to decrease the spread of the most vigorous spreading introduced conifer species in New Zealand – contorta pine. While there is a range of non-biological control methods available, these methods can be difficult to apply in some locations and the potential overall cost of controlling the existing spread is very high. Biological control using an

agent that damages cones thereby reducing seeding and therefore spreading vigour has been suggested as a possible long-term solution.

The international success rates for biological control have been estimated at 33% although more recent success estimates for Hawaii and South Africa were 50% and 83% respectively (McFayden 1998). For New Zealand the success of weed biological control (including only those cases where sufficient time has passed since the introduction of agents) has been estimated at 83% (Fowler et al. 2000). New Zealand uses intensive testing of potential biological control agents before introductions. Up to 2000 there had been no known significant non-target effects in New Zealand resulting from biological control agents (Fowler et al. 2000).

The major concern with any biological control for contorta pine in New Zealand is that the agent could affect closely related pine species that are of great importance to the New Zealand economy, especially radiata pine. Brockerhoff et al. (2004) reviewed insects associated with the reproductive structures of contorta pine to determine whether there were any potentially suitable host-specific agents. They identified a specific group of the European pine cone weevil *Pissodes validirostris* (a complex of sibling species) as a potential agent. However, the possibility that a cone insect could act as a vector for the fungus that causes pitch canker disease, *Fusarium circinatum*, is a critical impediment to the use of biological control for pines species in New Zealand (Brockerhoff et al. 2004). While pitch canker is not currently in New Zealand, radiata pine, and especially the strains currently grown in New Zealand, are highly susceptible to the disease (Dick et al. 2004). While it is highly likely that the impact of pitch canker disease in pine nurseries would be major, the vulnerability of the plantations is uncertain. The current absences of the most potent insect vector groups would be a strong mitigating factor, although it is unclear whether infection from injuries (e.g. pruning) might be sufficient in the moist New Zealand climate (Dick et al. 2004).

Storer et al. (2004) stated that while none of three potential biological control candidates for contorta pine is a known vector of the fungus that causes pitch canker disease elsewhere in the world, one is a known congenic of a known vector (*Conophthorus ponderosae*) and another is a member of a genus able to carry the fungus (*Pissodes).* They observe that vectors that enter the host (e.g. cone beetles tunnel into the host and the pine cone weevil *P. validirostris* punctures the host to lay eggs) pose the greatest risk and that a shift in host species is possible. Infestation of contorta pine by the latter species is already a host shift. A further host-shift to radiata pine in the field in New Zealand is possible (Storer et al. 2004). Storer et al. (2004) observe that habitat use by the potential biocontrol agent *P. validiristris* suggest that it would associate with the fungus that causes pitch canker and so could aid the spread of this pathogen.

8.6 Management of wilding conifer stands

Some landowners with dense infestations of relatively mature wilding conifers have considered various options for managing those stands for economic benefit. These options have included management for logs (often not an option with unmanaged stands), firewood or pulpwood and more recently registration for carbon credits under the Emissions Trading Scheme. Under any of these options landowners could transition to species with lower spread risk.

The major problem with managing wilding forests for timber or fibre is that they have established 'by default' and are often of the less desirable timber species, of variable density and poor form, and sited in poorly accessed locations. Consequently, compared to deliberately sited and managed stands, they do not lend themselves to profitable management. There are some exceptions, one being at Mt Barker near Lake Colerdidge, where Corsican pine wildings have grown sufficiently densely to produce good post and pole roundwood on a site from which further spread is currently able to be controlled (Nick Ledgard, pers. comm.).

One option that has been investigated but not actively pursued is the harvesting and chipping of wilding conifers to provide energy for local users. Harvesting wilding conifers for energy purposes would probably be confined to locations with low harvest costs, i.e. flat to rolling terrain such as the Mckenzie Basin (Peter Weir, NZFOA, pers. comm.). It would be most efficient to use the biomass locally, for on-site use (water and space heating) rather than transporting it long distances. It would not be economic to truck it from the Mckenzie Basin to Christchurch, or to ship to a North Island thermal power station for electricity production (Peter Weir, NZFOA, pers. comm.).

A meeting to consider options for using wilding contorta pine from lands managed by members of the Lake Pukaki Wildling Tree Trust as an energy source was held in September 2009. Following this meeting, initial proposals were developed to investigate options. In the absence of policy direction from Government and because of the reluctance of potential users to make the initial moves these proposals have not been pursued further (Shaun Bowler, EECA, pers. comm.). For example, the EECA coal to wood heat conversion programme for schools has had lower uptake than heat pumps which are cheap to install. Uptake has also been low because it is relatively cheap to modify an existing coal burner to co-fire with wood pellets, rather than replace an existing boiler with a more efficient (and lower emission) purpose-built wood-chip boiler, even though locally sourced wood chip is a significantly cheaper fuel than wood pellets (Peter Weir, pers. comm.).

9 Wilding conifer agency management and funding

9.1 Pest-led and site-led pest management

Pest management strategies can be described as either "pest-led" or "site-led". Pest-led strategies are those that focus on the management of specific pest species, where-ever they may be. Regional pest management strategies typically focus on the management of specific species. Pest-led management is particularly appropriate for species or related groups of species that have particularly damaging impacts and may not yet occur in an area or may be at relatively low levels in most locations so that eradication or containment are feasible objectives. A focus on the individual or related groups of pest species is also appropriate where that pest/pest grouping is one that transforms the environment in which it occurs. These species are known as "transformer" species. The removal of transformer species before they substantially change the environment can provide large environmental gains.

Site-led pest management focuses on controlling all the pest species affecting an area. This strategy is based on the assumption that in some areas where one or several specific species are removed they are likely to be replaced by other pest species. A site-led strategy is commonly used by the Department of Conservation and for some regional council pest management. Typically sites that have high biodiversity values are identified as a priority and all pest species are managed on those sites. Coastal, lowland and some montane sites that can be invaded by many plant pests are often addressed via site-led management

A third strategy is a combination of "site-led" and "pest-led" management. This strategy is used in some regional pest management strategies. For example, the objective for wilding conifer management in the Canterbury RPMS is to protect biodiversity in targeted areas by eradicating all self-seeded wilding conifers in targeted high value areas.

9.2 Agency management and funding

The purpose for collating figures on expenditure and areas being controlled is to provide an indicative stock-take of existing expenditure and effort. It is NOT appropriate to calculate expenditure per hectare for different agencies. This is because control costs per hectare can vary many-fold depending on age and density of the wilding conifers, the stage in the control cycle, control targets, accessibility, ease of movement and any limitations on control methods that can be used. Per hectare costs for eradicating dense stands of mature wilding conifers in inaccessible locations are very high. Conversely, current costs per hectare are low when there are large areas with very low densities of wilding conifers. To make meaningful comparisons it would be necessary to have more detailed information on costs per hectare for different types of control in different contexts. It is unlikely that current agency costs data would be sufficiently detailed and consistent to permit such an analysis at this time.

9.2.1 Central Government

Appendix 8 contains an indicative summary of central government agency wilding conifer management activities and funding.

The largest central government expenditure on wilding conifer control is by the Department of Conservation. Current overall national expenditure is estimated at $3.5 million nationally (Keith Briden, Department of Conservation, pers. comm.). Some have questioned why not all this expenditure is included in Appendix 8. There are a range of reasons including: not all programmes that control wilding conifers may be included in a conservancy estimate (especially where there are site led programmes where a number of species are controlled); the absence of figures from some conservancies; different assumptions in estimating costs (does the figure for each conservancy include staff time and department vehicle use as well as operational expenditure on resources and contractors); not accounting for departmental overheads; and the absence of figures covering input from regional and national offices and research and development staff)

The Department has been undertaking wilding conifer control for at least 25 years in many conservancies. The Conservancy with the highest annual expenditure is Canterbury. Current annual expenditure is $600,000 although double this amount could easily be spent (Helen Braithwaite, Department of Conservation, pers. comm.) There are 400,000 hectares under active management with the main species controlled being contorta pine, mountain pine and Douglas fir (Helen Braithwaite, Department of Conservation, pers. comm.).

Expenditure on wilding conifer management in Southland Conservancy is nearly as high as for Canterbury ($590,000 in 2010/2011) although the budget is being reduced in 2011/2012. In Otago Conservancy $203,000 was spent in 2010/2011 on wilding conifer management in seven large conservation areas. There are a number of other protected areas in Otago with wilding conifer and often other weed species as well. The amount spent on site-led pest management (including wilding conifers) in these areas is not known. Nelson-Marlborough Conservancy spends approximately $208,000/ year to control wilding conifers on 119, 010 hectares. The main species controlled are contorta pine, Douglas fir and radiata pine.

In the North Island the Wellington-Hawke's Bay Conservancy spent $85,000 on the control of contorta pine on 14,000hectares in the Kaweka Ranges and eastern Ruahines. In some areas there are trees up to 45 years of age and densities of 10,000 trees per hectare. Management follows a regularly updated operational plan (Department of Conservation 2010).

The Department of Conservation's annual budget was increased in 2005 by $555,000 for high country wilding tree control (Parliamentary Commissioner for the Environment 2009). This was apparently a response to the Department of Conservation's request for up to $5.3 million annually until 2014 (Parliamentary Commissioner for the Environment 2009) based on the Department's South Island wilding conifer strategy. This strategy (Harding 2001) identified, and ranked for intervention, more than 250 sites (some being thousands of hectares in size) infested by wilding conifers in the South Island. Land acquired through the tenure review process also contained wilding conifers at varying densities. In her 2009 report on the high country tenure review and environmental stewardship, the Parliamentary Commissioner for Environment recommended that

the Ministers of Conservation and Tourism seek Cabinet approval for sufficient additional funding for a sustained woody weed eradication programme. This recognised that that the costs of wilding conifer control increased exponentially over time if the conifers are not addressed promptly and consistently, and that as eradication is labour intensive it could provide employment opportunities.

The Ministry of Defence has been controlling wilding contorta pine over 63,000 hectares at Waiouru for 40 years. The density of wilding conifers has been considerably reduced and the methodology used for control has changed over time. More details on the Ministry of Defence's control programme and the lessons that can be learnt from this are in a case study (Appendix 11.3). Currently much control is helicopter based. Annual expenditure is $900,000. LINZ spent $700,000 on woody weed control in the South Island high country in 2007/2008.

9.2.2 Local government

Appendix 9 contains a summary of regional council funding and direct wilding conifer management activities. This table is incomplete as some information is not available. The largest expenditure on an annual basis is by Canterbury Regional Council ($300,000), followed by Horizons ($125,000) and then Environment Southland. Environment Southland made a large one-off contribution ($300,000) to the Mid-Dome project in 2006. Otago Regional Council is unusual in that while there are extensive areas of wilding conifers within the region, it does not spend any money on direct management activities.

9.3 Community Organisations

Community trusts focusing on wilding conifer control have been formed in several areas. They have typically been established in areas of extensive wilding conifer infestation, usually across lands of a variety of tenures. Councils and Crown agencies are involved in most cases and often provide funding and other support. The Trusts also access a variety of other funding sources, a task that can be very onerous (especially for volunteers). The original sources of the infestations can be Crown (and sometimes council) legacy plantings, typically for soil and water conservation (e.g. Mid Dome) and research purposes (Craigeburn /Flock Hill). In the Marlborough Sounds the primary original sources are private plantations.

The major community trusts working specifically on wilding conifer eradication/ control include:

- Mid Dome Wilding Trees Charitable Trust (Appendix 11.5)
- Wakatipu Wilding Conifer Control Group (Appendix 11.6)
- Waimakariri Ecological and Landscape Restoration Alliance (WELRA) (http://www.welra.org.nz/)
- Marlborough Sounds Restoration Trust (http://www.soundsrestoration.org.nz/wilding-pine-control.html)

The case studies in Appendix 11 describe the relevant trust's activities, funding, successes, problems and lessons learnt. There are also some smaller trusts based on a small group of landowners (e.g. the Pukaki area is addressed Appendix 11.7). In some locations wilding conifer control is managed under the auspices of an existing community organisation (e.g. the Royal Forest and Bird Protection

Society based in Dunedin http://www.forestandbird.org.nz/branches/dunedin). A new project to remove wilding conifers from Abel Tasman National Park is being led by the Abel Tasman Birdsong Trust http://www.abeltasmanbirdsong.co.nz/news.htm. This will be modelled on the approach being taken by the Marlborough Sounds Restoration Trust and especially their work in Inner Queen Charlotte Sound (http://www.soundsrestoration.org.nz/wilding-pine-control.html).

9.4 Agency co-ordination

A *Pinus contorta* Coordinating Committee was established in 1990 following widespread recognition that large areas of the Central North Island's Volcanic Plateau had been invaded by *Pinus contorta* and that plant had been declared a Class B noxious weed in the region (in 1983). This committee meets every two years with the most recent meeting being in October 2010. Membership of the committee includes representatives from local councils, Crown agencies, land owners and managers.

The New Zealand Wilding Conifer Management Group began as an agency steering group for a three year Sustainable Farming Fund research based project addressing wilding conifers. At that time membership was concentrated in the South Island. Since that project finished in 2010, the group membership has widened and the group focus has broadened to include wilding conifer management policy. The email list for the Group is large and includes: researchers, councils, Department of Conservation research and pest management staff, LINZ, Ministry of Agriculture and Forestry, the Ministry of Defence, community organisations, landowners and forestry companies.

9.5 Biosecurity funding principles and the funding of wilding conifer management

The Ministry of Agriculture and Forestry uses the following questions/"principles" (derived from s61 of the Biosecurity Act) when considering options for biosecurity funding:

1. Which party is best placed to change their behaviour to reduce the costs of the service or the risks that give rise to the need for the service?
2. Which party is best placed to assess whether the benefits of the service at its current level of provision outweigh the costs and consequently influence the level of service provided?
3. Which party is best placed to determine whether the service at its current provision is being delivered most cost-effectively?

Applying these questions in the context of wilding conifer management finds two complicating factors: the presence of legacy plantings and the time lag between when the spread occurs and when the impacts are experienced.

In the context of Crown legacy plantings and their progeny there are a number of precedents where the Crown has funded environmental restoration activities needed to remedy problems caused by earlier Crown actions. Examples include: Crown funding for the restoration of Lake Taupo and the Rotorua Lakes, and for re-diverting the Kaituna River back into Maketu Estuary. The principles behind these programmes, and Crown acceptance of an obligation to remedy past environmental damage resulting from its actions, should be further investigated in the context of current and future funding for the management of past Crown plantings of spreading wilding conifers (and their consequential progeny).

10 Land use and wilding conifers

As discussed under impacts, wilding conifers can affect both pastoral farming and commercial forestry. As land use can change rapidly this means that the risk of wilding conifer establishment at a site can also change rapidly. While sheep browsing at levels greater than 0.5 stock units per hectare can be used as a wilding conifer control tool such levels are not necessarily possible on a consistent basis in many parts of the South Island high country and are not appropriate in protected areas. Intact indigenous tussock grasslands and shrublands are more resistant to wilding conifer invasion than areas that have been degraded by repeated fires and overgrazing (domestic or wild animals). Areas of lower stature vegetation (and mountain beech forest with canopy gaps and/or canopy thinning) are still vulnerable, especially to wilding conifer species with more shade tolerance (e.g. Douglas fir).

10.1 Changing South Island forestry patterns

Douglas fir is becoming more widely used in the South Island because:

- recent changes to the New Zealand Building Code relating to the mechanical stress grading of sawn timber for use in house construction means that radiata pine grown in many parts of the South Island does not consistently reach a sufficiently high grade for it to be sold for use in New Zealand house construction (Section 13.3)
- return to the pre-1994 situation allowing untreated Douglas fir to be used in New Zealand timber-framed homes
- some actual and potential disease risks for radiata pine
- ability to earn carbon credits via the emissions trading scheme (Climate Change response Act) or the permanent forest sink initiative (Forest Act and regulations)

This increase is coming about as growers either change species after harvesting or grow Douglas fir in new locations.

Section 2.1.4 described the changing wilding risk profile for Douglas fir. Managing this risk, plus the wilding risk potentially posed by certain other introduced conifer species, is a challenge requiring co-operation between different parties. A broad-based accord, developed between the forestry industry, Local Government New Zealand (on behalf of councils), Ministry of Agriculture and Forestry, Department of Conservation and LINZ could be part of the solution. The purpose of such an accord could be to develop protocols for the effective prevention and management of wilding conifers spread from planted forests. A recent example of such accord is the Clean Streams Accord 2003 (http://www.mfe.govt.nz/issues/land/rural/dairying-accord-may03.pdf).

10.2 Introduced conifer plantings adjoining and/or upwind of lands vulnerable to wilding conifers

Previous sections of the report (e.g. section 8.2) have discussed planting protocols for reducing the risk of wilding conifer spread. Some land covers are, however, particularly vulnerable to introduced conifer spread and particular care needs to be when planting introduced conifers adjacent to and/or upwind of these areas.

Many of the areas of greatest vulnerability to wilding conifers (refer section 4) are those managed by the Department of Conservation. Such areas may also be highly valuable from an ecological perspective. They may already be affected by wilding conifers sourced from early plantings. Some of these earlier plantings may have been undertaken by the Crown either on land that is now managed by the Department or in some cases now managed by forestry companies. Other sources include private and council plantings.

In addition to careful planting there are a number of other measures that can be taken to minimise future or current wilding conifer spread from forest plantations. Methods to reduce wilding conifer infestation in Mount Richmond Forest Park are discussed by Brown et al. (2010). These include removal of small high risk introduced conifer remnants that had been left after the main harvesting, removal of particularly high risk species (contorta pine), not planting Douglas fir in some sites and developing an accord between parties.

10.3 Forest Stewardship Council

The Forest Stewardship Council (FSC) is an international non-government organisation that provides a system for certifying forests and forest products that meet minimum environmental and social standards (www.fsc.org). The certification is carried out by accredited organisations (not the FSC itself). A certified forest is usually audited annually and can be issued with Corrective Action Requests to address non-compliance with agreed standards. These requests specify the changes needed to ensure that the FSC certification remains.

A number of criteria are to be met by those seeking certification. No genetically modified organisms are to be grown within a Certified Forest Unit (FMU). The Council's Policy of Association may prevent Certified Growers being associated with GMO initiatives (Peter Weir, New Zealand Forest Owners Association, pers. comm.)

Approximately 52% of the productive areas in New Zealand's plantation forests have FSC certification (New Zealand Forest Owners Association 2011). To date only the large companies have obtain FSC certification. An equivalent system is being developed for smaller forest owners (Peter Weir, New Zealand Forest Owners Association, pers. comm.). Provisions for minimising the ecological impacts from introduced conifers (especially wildings) are in a New Zealand FSC National Standard proposed for ratification by the Forest Stewardship Council with the indicators being developed by consensus in New Zealand (Peter Weir, New Zealand Forest Owners Association, pers. comm.) as follows:

"Criterion 6.9: The use of exotic species shall be controlled and actively monitored to avoid adverse ecological impacts

Indicator 6.9.1
Forest manager*s shall comply with any applicable regional* ***pest*** *management strategy where this identifies a wilding species as a* ***pest***

Indicator 6.9.2
Forest manager*s shall have in place a* ***Wilding Prevention Decision Support System*** *and prior to planting of exotics use this to assess the risk of wilding spread. Where the risk is high the* ***forest manager*** *will not plant without implementing appropriate ongoing control procedures.*

Indicator 6.9.3
In the absence of a species being identified in the regional ***pest*** *management strategy, the* ***forest manager*** *shall remove '****wildings****' in adjoining properties before seed production where:*

- *the adjoining property owner is agreeable to any wilding control activities required on his or her land, and*
- ***wildings*** *are clearly identified as the progeny of species planted within the plantation area; and*
- *wilding spread has occurred from plantations after the Standard becomes operative or from first certification"*

The FSC prohibits the use of a large number of chemicals in certified forests. This may have implications for wilding conifer control based on chemical use in some locations.

11 South Island High Country land management and implications for wilding conifer management

11.1 Pastoral lease land and wilding conifers

The South Island high country comprises about six million hectares (nearly one quarter of the New Zealand land area). In the 1840's and 1850's the Crown "purchased" the high country from Ngai Tahu. Land perceived to have agricultural potential was managed initially under limited term licences that evolved into the Crown Pastoral Leasehold system (Parliamentary Commissioner for the Environment 2009). The 1948 Land Act provided for transferable perpetually renewable pastoral leases. As at December 2008 there were approximately 1.7 million hectares of pastoral leases in the high country (Parliamentary Commissioner for the Environment 2009).

Under section 99 of the Land Act 1948, leases and licenses are to be properly farmed with "no waste", land to be kept free from wild animals, land to be clear of weeds, drains and watercourses to be kept open. There is to be no felling, removal, sale of any timber, tree or bush that is growing, standing or lying. Destruction or burning is to be prevented unless the Commissioner approves. The exceptions are the use of timber for any agricultural, pastoral, household, road-making, or building purpose or if the tree was planted by the lessee (s100). The land is to be kept clear of all noxious weeds and the provisions of the Noxious Plant Act 1978 are to be complied with. The Land Settlement Board is the sole judge of whether a lessee or licensee has complied with the required conditions in both the lease/license and the Act (s105).

Despite these requirements, tens of thousands of hectares of pastoral lease land is affected by wilding conifers. Examples include Braemar, Ferintosh, Balmoral, Irishman's Creek and Coronet Peak Stations (Parliamentary Commissioner for the Environment 2009). Former pastoral lease land badly affected by wilding conifers includes the Mackenzie Basin stations of Mt. Cook and Pukaki Downs.

Rabbit numbers in the high country are relatively low at present. However, even in the early 1990's the Government, regional councils and landowners spent $28 million over seven years on a Rabbit and Land Management Programme (Parliamentary Commissioner for the Environment 2009). Populations are likely to increase in the medium term as immunity to the rabbit calicivirus spreads. If required by pest management strategies future rabbit control may be at the expense of some wilding conifer control (Keith Briden, Department of Conservation, pers. comm.). While rabbits do eat very young wilding conifers, the associated thinning of the grassland vegetation due to rabbit browsing may well provide additional opportunities for wilding conifer establishment.

11.2 Tenure review

In the early 1980's some Otago high country farmers, suffering from low returns and high rabbit numbers, developed agreements under the Land Act with the then Department of Survey and Land Information and the Department of Conservation, whereby the leaseholders acquired freehold

tenure over part of the land (Parliamentary Commissioner for the Environment 2009). The rest of the land was retained by the Crown to be managed by the Department of Conservation under the Conservation and Reserves Acts. Thirty six leases were reviewed, resulting in the free-holding of 107, 000 hectares with 69,000 hectares transferring to public conservation land (Land Information New Zealand et al. 2008). A formal process for tenure review was brought in as part of the Crown Pastoral Land Act 1998 and has been used for subsequent tenure reviews.

As at 31 October 2010 (Parnell Trost, Ministry of Agriculture and Forestry, pers. comm.) substantive proposals had been put to leaseholders of 81 pastoral leases covering a total area of approximately 432,000 hectares. Approximately 209,000 hectares (48%) has been retained in Crown ownership as public conservation land, and 223,000 hectares (52%) has become freehold land. Five additional pastoral leases covering 126,000 hectares have been purchased by the Crown with the land becoming public conservation land. Overall the relatively productive low altitude terraces, fans and basins have been transferred to freehold title, while the colder, steeper higher altitude grasslands have become public conservation land (Parliamentary Commissioner for the Environment 2009).

The Parliamentary Commissioner for Environment (2009) observed that the tenure review process has treated the management of wilding conifers inconsistently. In the case of Rhoboro Downs the Commissioner of Crown Lands (CCL) was aware of dense infestations of wilding trees on land proposed for freeholding, but considered there was no requirement under the Crown Pastoral Lease Act to consider the spread of unwanted organisms such as wilding trees. However, in the case of the Cattle Flat tenure review a sustainable covenant was created for the freehold land requiring the landowner to control pines and other weeds.

Some of the land transferred to the Department of Conservation contained wilding conifers. While there has been some additional funding to address weed problems on this land this does not cover all the additional costs (Helen Braithwaite, Department of Conservation, pers. comm.).

12 Carbon management and implications for wilding conifer management

Sections 6.6 & 6.7 summarised the relevant statutes and regulations relating to carbon management. There are two schemes- the Emissions Trading Scheme (ETS) under the Climate Change Response Act 2002 and; the Permanent Forests Sink Initiative (PFSI) under the Forests Act 1949 and the Forests (Permanent Forest Sink) Regulations 2007. The ETS provides for landowners of certain types of forest land to obtain carbon credits (New Zealand units). Two types of land are distinguished:

- Post-1989 forests: Owners of new indigenous or introduced forests established after 31 December 1989 can apply to earn New Zealand units (NZUs) for increases in carbon stock from 1 January 2008. If the carbon in the forest is diminished then units must be surrendered. Participation is voluntary for post-1989 forest owners and if the forest is not registered the change in carbon stock defaults to the Crown
- Pre-1990 forests: These are forests that were already established as at 1 January 1990 and were in introduced forest species as at 1 January 2008. As long as pre-1990 forests are re-established after harvesting, or natural regeneration occurs, there are no liabilities in respect of carbon. Participation in the ETS is mandatory when more than 2ha is to be deforested in any 5 year period from 1 January 2008. New Zealand units must be surrendered for deforestation.

Pre-1990 forest owners can apply for a one-off allocation of NZUs in recognition of the impact of the ETS deforestation rules may have had on land values. The amount of units allocated per hectare (60, 39 or18) depends primarily on when the land was acquired. As an alternative pre-1990 landowners can apply for an exemption (from carbon liabilities) to clear less than 50ha (before 30 September 2011) or to clear tree weeds (various rounds). Tree weeds are either specified Schedule 7 of the Climate Change Regulations (Forestry Sector) or defined as a pest in a pest management strategy under the Biosecurity Act 1993. This includes all the problem wilding conifer species.

A different type of carbon credit is earned under the PFSI. The PFSI allows private landowners to receive Kyoto Protocol carbon units (Assigned Amount Units or AAUs) for new permanent forests actively established after 1 January 1990. These units represent the increase in carbon stored (I unit=1 tonne CO_2) and can be internationally traded. Covenants are registered on the title and any harvesting within the first 99 years must retain a minimum of 80% of the pre-harvest basal area/ha.

12.1 How these regimes can affect wilding conifer management

Wilding conifers can be found on pre 1990 and post 1989 forest land as defined in the ETS. The tree weed exemption provision has removed a potential liability for landowners/agencies/organisations removing wilding conifers from pre 1990 forest land. There is an application process to be followed and once approval has been given the landowner has two years to remove the tree weeds.

There is no prohibition on landowners registering areas of wilding conifers (for carbon credits (NZUs) under the Emissions Trading Scheme, as long as this is not contrary to provisions in Resource Management Act plans or a pest management strategy prepared under the Biosecurity Act. While the Resource Management Act provisions are relevant to new forest plantings, they do not affect wilding conifers as these are not planted and at the time of registration would be an existing "activity" for the purposes of the Act. While most relevant regional pest management strategies (prepared under the Biosecurity Act) have provisions requiring removal (progressive or otherwise) or containment of contorta pine in much or all of a region, few strategies require removal of any of the other wilding conifer species. Where removal is required this typically applies to one or two species (mountain pine and maybe Corsican pine) in part of a region. This means that most landowners with wilding conifer stands that meet the definition of a post-1989 forest will be able to register those stands to gain carbon credits without any obligation to manage subsequent wilding conifer spread.

Where forests are registered for the permanent forest sink initiative (obtaining credit for carbon sequestration via AAUs), there are no requirements that such registration not be contrary with provisions in Resource Management Act plans and/or regional pest management strategies. It may be possible to exclude some wildling conifers from the PFSI as it could be argued that there may not have been active steps taken to create the eligible forest. Conversely it could be argued that the landowner facilitated natural regeneration by leaving wilding conifers/ not grazing an area. As with the ETS there is no requirement for those gaining AAUs to manage any subsequent wilding conifer spread.

Some landowners have already registered wilding conifers under the ETS. Where land is no longer able to be used to generate income from farming, leaving the wilding conifers and registering the land with the conifers for carbon credits under either the ETS or the PFSI, may provide the only option for a financial return. With many landowners unable to afford removing existing wilding conifers, especially if they have been left for some years, registration for carbon credits may be a very attractive option. Once registered, a landowner may find there will be a significant financial penalty to pay to remove a wilding conifer forest. This penalty would be a major disincentive for removal. There is a risk that the effectiveness of community programmes to remove wilding conifers from some areas may be compromised if a number of landowners have registered their wilding conifers under the ETS or the PFSI.

It is acknowledged that at least one property (Pukaki Downs) has used funds earned from wilding conifer carbon credits to purchase equipment used to remove other areas of wilding conifers (Elaine Curin, pers. comm.). The converse is that some landowners who may have been prepared to remove wilding conifers (especially if resources had been available) are or may register their wilding conifer forest in the ETS or PFSI.

13 Research of relevance to wilding conifers and their management

13.1 Existing research

Appendix 10 contains summary tables of direct and indirect research programmes of relevance to wilding conifers. Some of this research is directly applicable to management (e.g. developing the "best" herbicide mixes; modelling potential future spread of wilding conifers) while other research provides information about ecological patterns and processes and how these can be affected by wilding conifers. The research on natural ecological (including succession) processes in areas particularly at risk of wilding conifer invasion, along with research on the impacts of introduced conifers on above and below ground biota, helps managers better understand the wider environmental impacts and identify priorities for management.

The results from a number of the research programmes have been incorporated into this report. This includes research on existing distribution of wilding conifers (Section 3.2), potential future spread of wilding conifers (Section 5), current succession processes in areas at risk from wilding conifers (Sections 4.2 and 4.3), the effects of wilding conifers and their removal on natural succession processes in different environments (Section 4.4), and the impacts of conifers on above and below ground biota (Section 4.6).

There are gaps with funding existing research programmes including: modelling the risk of future-spread of wilding conifers; and evaluating long-term succession processes resulting from different control methods in different environments. Some of the datasets used for modelling potential future wilding conifer spread need to be upgraded (section 5). Funding is needed for this. One major gap is a single dataset of wilding conifer distribution in the North Island.

13.2 Potential future research and monitoring

A major priority necessary for the accurate monitoring of change and modelling potential future spread is the development of a clear baseline of current wilding conifer extent and intensity (species and density). It is suggested that centrally managed spatial database, that allows updates and use of the data by many would provide most flexibility. This could be linked to a proposed national weeds distribution database (Sherman Smith, Ministry of Agriculture and Forestry, pers. comm.). It is suggested that the requirements for the wilding conifers component of the database would need to be clearly specified by users along with standards for data collection and assessments of the accuracy of particular data sets.

A national database established using consistent standards could be used to further refine models for predicting potential future wilding conifer spread. The new electronic wilding conifer Decision Support System (DSS) would benefit from some field assessments, especially to refine assessments involving Douglas fir in different parts of New Zealand. Other suggested refinements include:

- Adjusting species growth (spreading vigour) assessment to better reflect the risk of different species in different parts of New Zealand different parts of New Zealand
- Reducing the weighting for species palatability as a low score only indicates a low risk if there are stock present
- Recognising that downwind land use can quickly change (e.g. from intensive grazing to no-grazing and this may even take place between the time of approval to the time of planting)
- Recognising that strong winds from unusual directions at certain times of year can lead to significant wilding conifers spread (e.g. wilding spread from Hanmer Forest to the Clarence catchment)
- Building in weightings that recognise the different contributions that different factors make to overall spread risk over time

There are a variety of drivers leading to an increase in Douglas fir plantings in both the North and South Island (Sections 10). In recent years the levels of Douglas fir mycorrihizza in the environment have increased and this is thought to be a major reason for the observed recent increase in successful regeneration in the wild and spread into native ecosystems (Section 2.1.4). A worthwhile area for future research would be to assess the potential spread of Douglas fir and the impacts of that. This would include a determination of its existing extent (part of compiling a database of current extent of wilding conifer species), and research into Douglas fir ecology and interactions with other components of the ecosystem in different New Zealand environments. This research should also evaluate the impacts of wilding Douglas fir on natural ecosystems and how these impacts could be mitigated.

Another useful area for research would be to develop a visualisation tool that can be used to demonstrate visually the impacts of different decisions and management regimes for wilding conifers for an area over time. Such a tool would be useful for both decision-makers and the public as it would provide an easy to understand representation of potential impacts of different scenarios. It would however, be important to link visual changes with information about other changes that may not be so readily depicted by visual images.

Another area that would benefit from additional research is the evaluation of ecosystem responses following the removal of introduced conifers. Aspects of particular relevance include: the potential subsequent re-invasion by introduced conifers or other weedy species, and to what extent ecological values will be restored in different environments. Suggested areas for research include: the post-removal or legacy effects of pines on soil nutrients and soil biota; weed invasions following introduced conifer removal; and changes in native vegetation over time following introduced conifer removal (Ian Dickie, Landcare Research, pers. comm.).

Restrictions on investment in wilding conifer control operations have limited the effectiveness of some operations, especially if there is inadequate follow-up control. One research option could be to develop research-based economic models for wilding conifer removal, including cost of removal and longer-term maintenance costs (Ian Dickie, Landcare Research, pers. comm.).

Potential funding options for such research could include: Envirolink tools, medium and small advice grants for universities and Crown Research Institutes; the Sustainable Land Management and

Climate Change programme and the Sustainable Farming Fund. Some Crown Research Institutes have funded relevant current research from long-term research funds (e.g. Landcare Research OBI "beating weeds") or short-term funds (e.g. Scion's capability funds for 2010-2011). Such funds may or may not be available in future.

13.3 Research into less spread prone hybrids and sterile conifers

During the investigations for this report a number of people suggested that a potential future preventative solution to the wilding conifer problem would be the development and use of sterile conifers. The joint submission from the New Zealand Ecological Society and New Zealand Society of Soil Science to the Ministerial High Country Review Committee (Floate 1994) suggested the use of Leyland cypress and *Pinus attenuata x radiata* to reduce wilding conifer spread.

Pinus attenuata and *P. radiata* are two North American species that only occupy contiguous areas in nature near Ano Nuevo Point, coastal California where some natural hybrids have been found (Bannister 1958). In New Zealand the two species were grown together for many years and by 1958 hybrids had been found in a number of locations (Bannister 1958). Bannister (1958) thought that some of these hybrids were different from those found in nature, possibly because some of the *P. attenuata* seed may have been derived from non-coastal USA.

Trials comparing the growth of *P. radiata, P. attenuata* and F1 hybrids between them in dry inland South Island sites, found that on the coldest sites (Balmoral Station and Ribbonwood) the hybrid grew fastest and was relatively tolerant of snow, while on milder sites (Eyrewell) *P. radiata* grew fastest (Dungey et al. 2011). Dungey et al. (2011) suggested that this hybrid offered an alternative to spread-prone species such as contorta pine and Scots pine.

It has been suggested that the use of the Cedros Island provenance of radiata pine *(P. radiata* var *binata*) crossed with *P attenuata* would be even better than the standard radiata – attenuata hybrid in the dry Mackenzie Basin (Charlie Low, pers. comm.). Cedros radiata is from dry Cedros Island and grows a very long tap root. Cedros radiata juvenile wood density is about 10% higher than that of radiata pine. This could be beneficial given that the outerwood wood density for *P. radiata* is low in most of the South Island and that only the Nelson-Marlborough *P. radiata* is of high density (Radiata Pine Breeding Co 2003) and thus likely to have a high proportion of the sawlog pass the machine stress grading tests now required in timber used for house construction. As such this hybrid may be an alternative to relatively spread-prone Douglas fir (which is being seen as the alternative to radiata pine in much of the South Island given its suitability for house construction), especially in drier inland sites. Further research would need to clarify the suitability of the timber from the hybrid *P. radiata* var *binata x P attenuata* for house construction and related purposes.

A potential area for research is the development sterile conifers which, when planted in the environment, would not produce viable seed. Of particular priority would be a sterile Douglas fir as this is likely to be planted in larger amounts in potentially vulnerable locations (Section 10.1). Investigations to date indicate that it may be very difficult to develop and propagate a sterile Douglas fir in a timely way using conventional breeding techniques. This means that some form of

genetic modification may be required. Broad-based public support would be required for the development of a genetically modified Douglas fir. Unless there are changes in the relevant Forest Stewardship Council (FSC) policies the development and use of genetically modified Douglas fir may also mean that a forest would not be eligible for FSC certification.

Sterile trees are a long-term option. They will not address the existing and near-future sources of wilding conifer seed.

14 Public values, perceptions and preferences as they relate to wilding conifers

14.1 Perceptions of wilding conifer management

Woods (2004) observed that some people oppose wilding conifer control. This could be because they prefer forest to grassland, or that they consider introduced conifers are replacing the native forests of the past. In landscapes dominated by low stature native vegetation some people are concerned about unsightly wilding conifer control that leaves the dead conifers standing. This concern is most prevalent in high profile locations with low-stature indigenous vegetation (e.g. Twizel-Pukaki-Aoraki/Mount Cook area).

Woods (2004) commented that many people had inaccurate perceptions of wilding conifer management requirements. When there are few wilding conifers, people tend to think that there is not a problem and so nothing needs to be done. When the trees are left to spread, control is then considered too difficult. Woods observed that another common misperception was that once there were no longer any trees visible there was no problem. This perspective does not recognise that to retain the benefits of work already completed periodic follow-up control is needed to remove small trees left behind and new trees resulting from germination of the soil seedbank.

A number of studies have shown that there can be differences between what people perceive as natural and what actually is natural (e.g. Purcell & Lamb 1990). Appropriate education and information can reduce the gap between perception and reality (e.g.Kerr & Sharp 2007).

14.2 Determining preferences and values

Several New Zealand studies have used Q-sort methodology (ranking photographs in order of preference) to determine community landscape preferences. Typically such studies identify several groupings of people. These groupings are given labels based on the values or preferences their choices represent.

Hock et al. (2001) used this approach and in-depth interviews to ascertain the land use preferences of 83 local stakeholders from the Mackenzie/Waitaki Basin area. They identified three preference themes: “plantation”, “pasture/tress”, and “conservation”. Those who were aligned with the “plantation” theme had a preference for timber production on hills, lower slopes and high-rainfall flats, with soil conservation on low-rainfall flats. Some importance was given to wilding conifer

management. Those aligning to the pasture/trees theme were interested in the higher productivity of combining improved grazing with some timber production and associated wilding conifer management. The third group ("conservation") had a preference for land retirement (destocking) and retention of the existing views on the flats. Some plantation forestry with wilding conifer management was acceptable on the hills. On the flats improved pasture with shelterbelts was preferred. A consistent feature of this theme was wilding conifer management to prevent suppression of the indigenous vegetation.

Each of the three "groups" expressed different visual preferences. The "plantation group" indicated a preference for plantations having boundary lines softened by wilding conifer spread. The "pasture/trees group" showed a strong preference for clear boundaries between plantations, woodlots and pasture. Views of the mountains from the flats were important. Those aligning to the "conservation" theme showed a clear preference for land use to reflect the original cover of open tussock grassland with only small amounts of trees. While small well-defined plantations were acceptable on hills and slopes, it was important to retain the sense of openness on the low-rainfall flats. (Hock et al. 2001) found no strong links between stakeholder type and preference expressed.

Bell et al. (2009) describe an economic valuation method that incorporates within Cost-Benefit-Analyses, the level to which people value the prevention of potential pest impacts on biodiversity. In this method they derived 36 value estimates from across 11 New Zealand populations to form the basis of a biodiversity values database (BVD). Choice modelling was used to derive the values in the BVD. The method uses surveys to ask people what they are willing to pay (WTP) for specific marginal changes in the environment. In this case the focus was on identifying the value people attach to preventing impacts on specific biodiversity values resulting from a pest species.

(Kerr & Sharp 2007) reported on the application of a choice modelling experiment to estimate community preferences and values associated with the impact of wilding pines on indigenous species in the South Island high country. Individuals were asked to indicate their preference for alternative high country scenarios (developed using information about wilding conifer tree biology, spread patterns and implications). Results from two focus group meetings-one in each of Christchurch and Auckland- were used to design the actual experiment. The focus group participants generally recognised the landscape implications of wilding pine trees but had little understanding of ecological impacts. There was little interest in addressing wilding pine invasions by those who both lived a long way away and were not informed about the impacts of wilding pines.

For the actual experiment Kerr & Sharp (2007) used the MacKenzie Basin with 165 South Island participants from communities in Christchurch, Twizel, Timaru and Fairlie. Three threatened or endangered native species (the low shrub *Hebe cupressoides*; the robust-grasshopper (*Brachaspis robustus*; and the fish bignose galaxias (*Galaxias macronasus*)) provided the focus for assessing the effects of wilding pines on indigenous biodiversity. The participants were informed about wilding conifers, their impacts and the status of the three indigenous species and so could be classed as "informed" when they made their choices. Participants were asked to specify how much their household would be prepared to pay per year for the next five years to control wilding conifers so that the indigenous species in question did not become extinct. Kerr & Sharp (2007) found that the differences between the four communities were less than the differences within communities.

While there were some clear differences within a community based on socio-economic factors (e.g. richer Fairlie and Twizel participants placed a lower value on preserving the bignose galaxias) there were no consistent trends across the communities.

Overall the participants preferred less wilding pine cover. For any amount of cover they preferred that the blocks not be contiguous. They valued the continued existence of the three threatened species and preferred lower personal costs. The amounts communities were prepared to pay per household per year for the next five years to control the wilding pines so that the indigenous shrub *Hebe cupressoides* did not become extinct in the Mackenzie Basin were $95 (Christchurch), $71 (Twizel), $55 (Timaru) and $33 (Fairlie). To illustrate the levels the community might be prepared to pay Kerr & Sharp (2007) used the lowest (Fairlie) value ($33 per year for 5 years). With a discount rate of 10% this totalled $138 per household. When they aggregated this over 300,000 South Island households this gave a total present value benefit of $41 million for controlling wilding conifers to prevent the local extinction of the hebe. Using the mid-point figures of $70 for *Hebe cupressoides,* $120 for the robust grasshopper and $140 for the bignose Galaxias, Kerr & Sharp (2007) calculated community figures of $50M, $115M and $130M respectively. They concluded that these figures indicated the community was willing to prepare large amounts of money to manage wilding pines and other threats to these species. These figures were, however, derived from participants who had been informed about wilding conifers and their potential impacts of specific threatened indigenous species. For such figures to be potentially applicable at the wider community level it would be necessary to have a more informed public.

Bell et al. (2009) describe the process of benefit transfer (BT) which compares the original research to the new situation to see whether the WTP values (from an existing study) can be confidently transferred to the new situation. Comparisons address the similarity of:

- The physical characteristics of the sites
- The characteristics of the sample and wider populations
- The values assessed

The process of benefit transfer would allow the results of specific studies to be applied more widely.

15 Barriers to effective wilding conifer management

Barriers to effective wilding conifer management can be divided into four categories: funding, capacity, perception and strategic/policy/process. Table 6 lists the key barriers by category.

Table 6: Barriers to effective wilding conifer management

Category	**Barrier**
Funding	• Public agencies have insufficient funding for effective long-term control of wilding conifers as required to protect and restore environmental values • Funding for the Department of Conservation is continuing to be cut • Landowners and land occupiers, especially those with extensive areas of marginal lands, often have insufficient funding to effectively control wilding conifers on land they own/occupy • Community trusts can have difficulty accessing funding which limits their ability to effectively control wilding conifers • The requirement for multiple applications and the sometimes onerous auditing requirements can impose substantial burdens on community groups involved in wilding conifer control • The costs of key control tools (helicopters and fuel) are high and have risen faster than inflation • Lack of well –proven techniques for the cost-effective removal of dense stands of wilding conifers
Capacity/ knowledge	• Current restructuring of the Department of Conservation may remove some of its core technical capacity for developing and trialling new cost effective control methods and delivering effective wilding conifer management • Where a wilding conifer problem has been left on a property for many years, control today can be beyond the capacity of the current owner/occupier
Perception	• When there are no visible tall conifers decision-makers can perceive there is no problem (and so no funding is needed). In other words other projects have higher priority. This can limit the availability of funding for early control of wilding conifers spread (Stitch In Time Saves Nine") and for follow-up control after the initial major control operations • Success means there is nothing (no wilding conifer problem) to see • Landowners can be suspicious of funding assistance that is tied to some type of council covenant securing public money (a major concern can be a perception that there may be a requirement for future public access) • Pest plants are not seen as a major problem by many. Some may see wilding conifers (and some other weed species) as attractive in some areas, others may not care • Reticence by some landowners to undertake early control (Stitch in Time Saves Nine) • There can be a perceived conflict within councils about both promoting tree planting and tree removal • Beliefs that long-term benefits (of effective control) should be discounted at an inappropriately high rate
Strategic/	• There is no national strategy to guide priority setting and facilitate co-

Category	Barrier
policy/ process	ordination • The Emissions Trading Scheme has created a further disincentive to control wilding conifers for some landowners • Objectives and strategies for wilding conifer management can vary considerably between councils and other management agencies • Inconsistent local government regulatory regime for introduced conifer planting and associated management • A lack of consistent methodology for monitoring hinders effective reporting (scale of the problem and successes) • Biosecurity Act requirements for a cost-benefit analysis and sector opposition mean that it is very difficult to include potential or actual commercial species within a regional pest management strategy (limits what councils can do)
Other barriers	• Some landowners/occupiers are unwilling to control wilding conifers on their properties for undisclosed reasons • Personality conflicts, egos, parochialism, and politics

16 Integrated management

16.1 Co-ordination at different levels

Wilding conifers do not respect property boundaries. Effective long-term control often requires a co-ordinated multi-organisation /multi-landowner approach, especially when the conifers in an area are on lands under different tenures. Examples of co-ordinated management include:

- The Central North Island Contorta Co-ordinating Group (Section 9.4)
- Mid Dome Wilding Trees Charitable Trust (Appendix 11.5)
- Wakatipu Wilding Conifer Control Group (Appendix 11.6)
- Waimakariri Ecological and Landscape Restoration Trust
- Marlborough Sounds Restoration Trust

At a different level the New Zealand Wilding Conifer Management Group has evolved from a stakeholder oversight role for a Sustainable Farming Fund (SFF) research programme on wilding conifers to a broader role that addresses wilding conifer strategy and management (Section 9.4). A wide range of organisations and interests are represented on this group which has been meeting periodically in Christchurch since the completion of the Sustainable Farming Fund research programme in mid 2010. The science connection has been maintained as Scion has continued to provide administration services to the group, and the meetings since the completion of the SFF programme have included reporting from relevant science projects. The Group has discussed an initial discussion paper and parts of this report at meetings in May, July and September 2011. In the case of the last two meetings, discussions of sections of this report formed the main focus of the meeting. A number of organisations and individuals from those organisations that are represented on the Wilding Conifer Management Group provided feedback on earlier drafts of this report.

At a more local level co-ordination between groups of landowners/ land managers could improve wilding conifer control outcomes at the local level. Agreements between those with planted introduced conifer forests and neighbours may be needed to align management near property boundaries and to allow a forest owner access (to another property) to remove wilding conifers resulting from introduced conifer forests.

16.2 National strategy

A number of people involved with wilding conifer management have expressed a strong desire for national co-ordination via a national strategy for wilding conifer management. This approach is favoured because a national strategy would:

- raise the profile of the wilding conifer problem;
- assist with obtaining the necessary funding on a regular basis;
- help achieve consistency in approach to wilding conifers in regional pest management strategies, and would
- assist with priority setting for wilding conifer management across lands of different tenures.

There are several possible mechanisms for preparing such a strategy depending on the level of statutory backing required, the scope of the strategy and the process to be followed. One option would be a completely non-statutory approach addressing matters covered under the Biosecurity and Resource Management Acts as well education, research and monitoring, and co-ordination across legislation and between organisations. Implementation could be via a variety of mechanisms. Another option would be to develop a national pest management plan (under the new provisions being introduced via the Biosecurity Law Reform Act 2010). This would have a narrower focus than the previous option given that it would be prepared within the scope of a single statute.

Potential agencies for leading the preparation of such a strategy seem to be limited. While the agency responsible for leading the preparation of a national strategy could be one of the four government departments involved in the New Zealand Wildling Conifer Management Group (Ministry of Agriculture and Forestry, Department of Conservation, LINZ, Ministry of Defence), the Ministry of Agriculture and Forestry seems to be most appropriate given its biosecurity functions including its roles in administering the Biosecurity Act. The other three Departments primarily manage wilding conifers on lands they administer (although Department of Conservation does some wilding conifer management on lands of other tenures on behalf of councils and landowners) The general consensus of those consulted seems to be that with its lead role for Biosecurity, the Ministry of Agriculture and Forestry would be ideally placed to lead the preparation of such a strategy.

16.3 Case studies

Appendix 11 contains a set of case studies illustrating different contexts and management regimes for addressing wilding conifer problems. The purpose of this section of work was to identify lessons that could be learnt from a group of case studies addressing different approaches and contexts for wilding conifer management. The following text sets out the key lessons learnt from each of these case studies

Case study 1: Wilding control using more cost-effective techniques on lands of different tenure in the Mackenzie Basin
Lessons learnt:

1. Effective co-ordination between public agencies can achieve more than agencies acting alone
2. Working with local contractors helped the Department of Conservation with developing and refining control methods, and with making them available to others. This helped facilitate effective control on neighbouring properties, thereby reducing long-term risks for the Department of Conservation managed lands
3. Sufficient resources and the refinement and application of innovative methods on Department of Conservation managed land means that by the end of the 2011-2012 summer wilding conifers will be controlled on all current public conservation land in the Mackenzie Basin. Ongoing maintenance control will be required to address trees missed and seedlings germinating from the soil seed bank (including that blown in from other properties)

Case study 2: An example of sustained control of contorta pine over many years by the Ministry of Defence

Lessons learnt

- Good science and technology improvements lead to more effective wilding conifer management and monitoring over larger areas
- In comparison with most other wilding conifer control programmes this programme has been very well resourced over the years. This has facilitated the use of adaptive management to revise and refine cortorta pine control methods in some very challenging situations (e.g. steep gorges, zones with un-exploded ordinance)
- Contorta pine will persist on sites where there is a local or neighbouring ongoing source of seed, even if there are contorta pine control operations
- The length of the control cycle used in wilding conifer control programmes needs to be selected with great care. In the central North Island a contorta pine control cycle of four years meant that 1-2 year-old trees were often not detected in tussock grasslands and so they had time to produce viable seed before the next control cycle. This allowed medium-high densities of contorta pine to persist in spite of ongoing control. Reducing the control cycle in open areas to 3 years led to significant reductions in contorta pine densities
- Contorta pine is harder to detect and access in scrub and so is more likely to produce viable seed before it is removed. Annual aerial control was recommended for scrub areas to improve the chances of detection and removal at the earliest possibly time
- Natural succession processes in areas of human-induced grasslands will change the impacts of, and control requirements for, different weed species, including wilding conifers. These succession processes are more rapid in the North Island

Case study 3: Horizons Regional Council comprehensive RPMS methods for the control and containment of contorta pine

Lessons learnt:

1. Where RPMS rules for a particular species require landowners/land occupiers to control a species that some of those landowners/land managers perceive may have some economic value, compliance may be patchy and the outcome less than expected
2. A comprehensive approach, including appropriate rules, active negotiation with agencies and landowners/ land managers, and direct control work by the council was needed to achieve comprehensive control of contorta pine in an area with a zero density target

Case study 4: Mid Dome, an example of combined agency and community action in spite of escalating costs

Lessons learnt

- Delays in controlling/ eradicating problem introduced conifer plantings and their wilding offspring can lead to a rapid escalation in costs (from $900,000 in 1999 to $8.5 million in 2008)
- Incomplete or inadequate control achieves little
- Where many different landowners and agencies have land in an area that is affected by wilding conifers co-ordination is essential. This is usually via a group which needs to be formalised if wants to raise revenue.

- Where there is a complex mosaic of land ownership/ management it is helpful to have a combined agreed strategy and operational plans
- Some historic soil conservation plantings were, in spite of good intentions, unnecessary and ineffective. Scientific investigations are providing us with a better understanding of New Zealand's geology and other natural processes and what types of soil conservation interventions might be appropriate/ inappropriate in different locations
- Managers can be slow to stop planting species that are known to spread
- It can be very difficult to obtain the funding needed to control large dense infestations of wilding conifers

Case study 5: Wakatipu wilding conifer control- a community group, district council and the Department of Conservation working together

Lessons learnt:

- The establishment of a community-based organisation with partnerships with landowners and agencies (excluding Otago Regional Council) has led to the involvement of more people in wilding conifer management and access to increased resources
- The annual grant to the WWCCG by the Queenstown District Council provides credibility to the Group and assists them in obtaining more funding
- Otago Regional Council is unusual (for a Regional Council) in not wanting to partner with a broad-based community wilding conifer control organisation nor to collaborate with agencies involved in controlling wilding conifers in their region

Case study 6: Pukaki Downs Station alternative approaches to managing wilding conifers that spread from Crown legacy plantings

Lessons learnt

- The ETS can provide a potential funding source for the containment and then progressive removal of wilding conifers from a property by systematically replacing the wilding trees in the containment area with species with a lower risk of spread.
- The ETS can also fund the retention of wilding conifers without a requirement for those wildings to be retained, nor progressively replaced by other species with a lower risk of spreading. The inappropriate use of the ETS could lead to the increase in wilding conifer spread in some areas (possibly even adjoining properties that are using ETS funding to remove wilding conifers). ETS and Biosecurity outcomes may be optimised if registration of tree weeds under the ETS is restricted to those situations where there is:
    - an enforceable management plan requiring that all wilding conifer spread beyond the registered area be prevented;
    - a requirement that a non-spreading tree buffer is planted around the registered area; and
    - a requirement that the tree weeds in the registered area are progressively replaced by non-spreading tree species.

16.4 Successes

It is easy to become overwhelmed at the scale of the wilding conifer problem, particularly in some locations. There have, however, been many successes. With better co-ordination, improved

information about the most effective approaches in different situations and the long-term management implications of those approaches wilding conifer management has the potential to become more effective and efficient over larger areas.   Key challenges such as resource shortfalls do threaten some of these potential gains.

There are many examples of successful operations and it may be worthwhile to set up a project to systematically document these, both to reward those who have worked long and hard to control wilding conifers and to demonstrate the value and effectiveness of work done to the public and decision-makers.

Several of the case studies (Appendix 11) document important success stories. Other examples include (Lynne Huggins, Department of Conservation, pers. comm.):

- Mount Bee in Southland. Here, the former New Zealand Forest Service had planted approximately 3000ha (mainly contorta pine, mountain pines, mountain alder and occasionally radiata pine). There was also some Douglas fir that had spread from adjoining plantations. Control took 15 years. Now Department of Conservation staff and contractors just monitor every two years
- The Blue Mountains in Southland. Here a variety of pine species (including contorta pine, ponderosa pine, mountain pines and radiata pine) have been cleared from 15,000ha of tussock tops by Department of Conservation staff and contractors. However, Douglas fir wildings are now arriving from surrounding plantations

16.5 Quick wins

A two day meeting of the New Zealand Wilding Conifer Management Group (14-15 September 2011) suggested a set of potential quick wins that could possibly be implemented while a national strategy was being prepared or developed more fully as part of the strategy preparation process. These suggestions were:

- Department of Conservation operational training workshops for agencies (to ensure correct best practice implementation of new methods being developed)
- Social marketing (employ social marketer to communicate information to a broader group of people
- Professional selling of messages about work done using interpretation panels at key sites (especially by highways)
- Request the Parliamentary Commissioner for the Environment new state of environment monitoring (if implemented) include monitoring of the distribution and density of wilding conifers using standard protocols
- Post videos of before, during and after clearance/control on the internet
- Use case studies and other spatial information sources to demonstrate what has been done over time
- Education, especially for agency decision-makers, on benefits of *stitch-in-time-saves-nine*
- Provide advice to community groups wanting to manage wilding conifers
- Encourage back country users (possibly via clubs) to carry a saw to cut down wilding conifers that they find (Possibly seek sponsorship for this)

- Encourage backcountry users to GPS the locations of wilding conifers and provide that information to the appropriate regional council
- Develop a visualisation tool to show decision-makers the implications of different wilding conifer scenarios over time
- Establish a contestable fund for *stitch-in-time-saves-nine* wilding conifer control projects
- Lead agency to co-ordinate information sharing
- Implement a requirement for an effective wilding conifer management plan at time of registration in the ETS
- Develop a brand and marketing plan
- Celebrate success stories
- Provide assistance to community groups, especially in first few years

A number of these suggestions are included within the options (section 17) and the recommendations (section 18).

17 Issues and options

This chapter sets out the issues that have been identified in preceding chapters. An issue can be an unresolved problem, a threat or an unexploited opportunity. Possible options are listed for each issue or group of related issues. The status quo is not usually listed as a possible option because one of the purposes of this chapter is to identify possible resolutions to existing issues.

Extensive and often conflicting feedback was received on various drafts of this section of the report. On some issues there was no agreement on possible solutions. For several issues it appears that no options developed so far would attract universal support. It may be necessary to make some difficult decisions if the wilding conifer problem is to be adequately addressed over time.

17.1 Current and future extent of wilding conifers

Issues

1. A large area in the eastern South Island is affected by wilding conifers. In 2007 this was estimated to be approximately 805,000ha, which includes 185,000ha mapped as having a wilding cover. A further 660,000ha were identified as having received past control but in 2007 wilding conifer density was very low and these areas were not mapped as having wilding conifers (Section 3.2).

2. The area affected by wilding conifers in the North Island has not been fully mapped although it is estimated (Paul & Ledgard 2011) that approximately 300,000 hectares of land are affected by wilding conifers at various densities. (Section 3.2).

3. While a desktop study/interview review can identify specific areas where the problem of wilding conifers is increasing (e.g. Southland, inland Marlborough) and areas where the problem has reduced due to effective management (e.g. North Island Central Volcanic Plateau), it has not been possible to accurately define overall national trends. Nevertheless, there are a number of locations where the wilding conifer problem is increasing

4. Without timely control of problem plantings, and the associated wilding conifers and their progeny, the area affected by wilding conifers can increase exponentially along with wilding density and the costs of control

Options (one or all could be implemented)

See 17.18 National strategy and co-ordination, 17.13 Funding, 17.16 Monitoring and Reporting

17.2 Impacts of wilding conifers on indigenous ecosystems and species

Detailed explanatory material is in section 4 (impacts of wilding conifers).

Issues

1. Wilding conifers adversely affect and can replace low stature natural ecosystems composed of indigenous species (including tussock grasslands; sub-alpine ecosystems; dry intermontane basin ecosystems; geothermal ecosystems; ultramafic ecosystems; riverbeds; dunelands, rockfields, herbfields, cliffs and other coastal ecosystems). Local extinctions of indigenous ecological communities and plant or animal species are possible. Without effective and timely control of wilding conifers these changes can be largely irreversible.

2. Some species of wilding conifer are able to grow at altitudes above the treelines formed by indigenous species, thereby replacing indigenous sub-alpine and alpine ecosystems.

3. Introduced conifers (both planted and wilding) change soil chemistry, soil microbial composition and activity, as well as soil fauna. The long term impact of these changes on indigenous ecosystems is unknown.

4. Climate change is likely to reduce the resilience of already-stressed indigenous ecosystems and they may become more vulnerable to invasion by wilding conifers and other weed species

5. In contrast to other wilding conifer species, Douglas fir is able to invade relatively intact indigenous grasslands and shrublands, as well as beech forest via canopy gaps and/or a thinning canopy (Refer 2.1.4, 4.1).

Options (one or all could be implemented)

1. Areas at particular risk of biodiversity loss (for ecosystems, species or genetic information) from wilding conifers (and other weed species) could be identified in a national wilding conifer management strategy (section 17.18), conservation management strategies and other relevant public agency planning documents

2. The prevention of indigenous biodiversity loss (at all levels) could be a priority objective for wilding conifer management, especially on public lands. This could be an objective for a national wilding conifer management strategy (Section 17.18), regional pest management strategies, conservation management strategies and other relevant public agency planning documents. Appropriate implementation measures would be required.

3. Options for seeking additional funding to eradicate wilding conifers (and other weed species) from areas where biodiversity values are threatened/at risk should be investigated. This funding would need to be sufficient to: remove high-risk wilding conifer source populations; monitor areas after wilding conifer removal; and remove subsequent conifer regeneration

4. Options for issue18.2. 5 are in 18.9 *Central government policy affecting species and locations planted.* Options for issue 18.2.4 are complex and extend beyond the scope of this report.

17.2.1 Impacts of wilding conifers on South Island dryland ecosystems

Issues

1. Disturbances resulting from a variety of human actions have had a profound effect on the indigenous woody flora of the South Island drylands and the re-establishment of many formerly common woody native species is likely to be slow or non-existent. It is likely that dryland secondary woody vegetation will be susceptible to dominance by various woody weed species , such as pines, Douglas fir, sycamore, larch and birch over extended time periods, especially in sites that are drier and have more frequent disturbance and have no (or minimal) seed sources for taller indigenous species (Section 4.2)

2. The succession towards indigenous woody vegetation in inland South Island dryland sites requires the control of both fire and transforming woody weeds, particularly Scotch broom, gorse and conifers. In these dry inland environments the indigenous woody (forest) vegetation is relatively short and open and may be vulnerable to introduced conifer (especially Douglas fir) seedling establishment (Section 4.2).

Option

1. Vulnerable dryland ecosystems should be clearly identified (at an appropriate scale) as part of option 17.2.1.

17.3 Impacts of wilding conifers on water and aquatic ecosystems

Issues

1. In catchments with long-term seasonal soil moisture deficits, significant areas of planted and wilding conifers can decrease surface water flows and aquifer recharge rates. This may adversely affect existing water users (including water supply, irrigation and hydro-electric power generation), instream ecological values and recreational users of the instream water (Section 4.8).

Options

1. Regional councils could identify at-risk catchments and include appropriate policies, rules and other methods in regional plans. These methods would apply to planted and possibly managed wilding conifer stands.
2. Regional pest management strategies/plans applying to areas with long-term seasonal soil-moisture deficits could assign a high priority to wilding conifer control for water and aquatic ecosystem purposes

17.4 Impacts of wilding conifers on production activities

Issues

1. Land used for extensive pastoral farming (especially where it is based on often degraded indigenous tussock grasslands) is highly vulnerable to invasion by woody (e.g. wilding

conifer) and herbaceous (e.g. *Hieracium*) weeds. Once wilding conifers become established on land of low economic value of this land for grazing, it is difficult for landowners to effectively control wilding conifers (Section 4.7)

2. Wilding conifers can affect some commercial forestry operations (there may be restrictions on areas that can planted because of the risk of wilding spread, it may be necessary to fund wilding conifer control and there may be additional land preparation costs)

Options for issue 1 where wilding conifers are not established (one or all could be implemented)

- Where the land and vegetation is suitable for grazing but vulnerable to wilding conifer spread (because of its location) landowners could graze sheep at stock levels of at least 0.6 stock units per hectare (to control any wilding conifer seedlings)
- Landowners could inspect areas that are vulnerable to wilding conifer spread on an annual basis and immediately remove any wilding conifers
- Councils could assist landowners who choose to retire land to encourage a denser ground cover (and greater resilience to wilding conifers invasion) through rate relief(possibly for covenanted areas) and/or assistance with animal pest control
- Landowners could retire vulnerable land to encourage a denser tussock and shrub cover
- Landowners could intensify land use on suitable land by oversowing, topdressing, and possibly irrigation, to allow higher stock numbers to be carried
- Landowners could intensify/ diversify land use on suitable land through the planting of non-spreading tree species or crops

Options for issue 2 where wilding conifers are established (one or all could be implemented)

- A fund could be established for landowners where the original source(s) of the wilding conifers are Crown legacy plantings. Landowners could apply to the fund for assistance with properly planned control operations
- Landowners could contain the most problematic conifers by techniques such as planting less invasive species around their margins (to reduce seed spread), progressively replacing highly invasive species (such as contorta pine) with less invasive species, and removing wildings that appear outside of the containment area. The use of wilding conifers as a local fuel source may help fund conversion to less invasive species
- A council could use its regional pest management strategy to identify priority areas for providing assistance to landowners to manage and contain wilding conifers
- Councils could assist groups of landowners to collaborate and work together to collectively address wilding conifers on their properties
- Foresters could proactively reduce wilding conifer spread (by carefully selecting planting locations, species to plant and planting designs); and remove wilding conifers prior to coning. The latter would require access arrangements to be negotiated where the spread is onto lands of other tenures.

17.5 Impacts of wilding conifers on landscape values

Issues

1. Community perspectives vary on the effects of introduced conifers on landscape values. This includes plantations at different stages in their management cycle and wilding conifers. It can be difficult to achieve community consensus, particularly in some locations

2. In the eastern South Island and Central North Island, the combination of planted and wilding conifers above a (currently unspecified) threshold changes a landscape from one dominated by a mosaic of indigenous grassland/scrub/shrubland/forest to one dominated by northern hemisphere conifer mosaics

3. The introduction of identified outstanding natural landscapes and associated policies and methods into Resource Management Act planning documents can be highly political. This can lead to considerable variation in how councils address landscape protection

Options (one or all could be implemented)

1. Landscape protection is addressed by local authorities using Resource Management Act instruments and processes
2. The recommended national strategy for wilding conifers (Refer16, 17. 18) could provide a forum for councils to discuss ways to implement more consistent approaches to landscape protection in the context of wilding conifer management
3. There could be national guidance (e.g. National Environmental Standard or a National Policy Statement under the Resource Management Act) on how local authorities should address landscape protection. This would be broader than just wilding conifer management

17.6 Legacy of previous introduced conifer plantings

17.6.1 Legacy plantings resulting from actions by central and local government

Issues

1. Previous central government conifer plantings for: erosion control/revegetation (e.g. Mid-Dome, Branch/Leatham catchments and various other parts of Marlborough); plantation forestry research/trials (e.g. Hamner and Craigeburn Forests); and hydro-electric power development mitigation (e.g. Lake Pukaki area); have caused the spread of wilding conifers onto public and private lands. The Crown's obligations for managing these plantings (Section 3.4) and the resultant wilding spread have not been clearly specified and accepted.

2. Former catchment authorities (catchment boards and commissions which were the forerunners of regional councils) planted various species of conifer and other tree species for soil conservation purposes. Wilding conifers have spread from some of these plantings onto public and private lands. Long-term responsibilities for management vary, especially for the wilding conifers spread.

3. These legacy conifer plantings and their wilding offspring are continuing to spread in many areas (E.g. Section 3.4).

Options (one or all could be implemented)

1. The Ministry of Agriculture and Forestry, in collaboration with the Department of Conservation, Ministry for the Environment, and Land Information New Zealand, could develop a proposal to establish a fund that would be used for effectively managing the effects of Crown legacy plantings of introduced conifer species. Such a contestable fund could be available for applications from public agencies, community trusts and landowners. The “Crown legacy plantings” fund could be available for applications to manage the associated wilding conifers including those one or more generations removed from the original plantings

2. A wilding conifer management strategy (Refer 16, 17.18) could: identify the location and extent of Crown legacy conifer plantings and subsequent wilding conifer spread; determine removal and other management priorities for Crown legacy plantings (and the associated wilding conifers); and develop a programme for implementation (including obtaining the necessary funding)

3. Regional pest management strategies/plans could identify the locations of past council introduced conifer plantings and the associated wilding spread. The strategy could determine appropriate management actions for these particular areas and set out an implementation programme. The locations addressed could include those with plantings made by constituent territorial local authorities

17.6.2 Legacy plantings resulting from private landowner/occupier actions

Issue

Earlier private plantings of conifer species in some locations (e.g. *Pinus contorta* shelterbelts and plantations) have facilitated the spread of wilding conifers onto public and private lands. Requirements for control are ongoing (Sections 3.3.2, 3.4).

Options (one or all could be implemented)

1. Regional pest management strategies could require landowners/land occupiers with plantings of conifer species that have a high risk of spread to remove those plantings or at least contain the plantings and remove any spread.
2. Regional councils could assist landowners with private legacy plantings of spreading conifer species to find funding outside of the landowner’s personal resources to help fund removals

17.7 Pastoral lease land and tenure review

17.7.1 Pastoral lease land affected by wilding conifers

Issue

Tens of thousands of hectares of pastoral lease land are affected by wilding conifers (Section 11).

Options (one or more are possible)

1. LINZ could undertake a review to determine the location, extent and densities of wilding trees and source plantings on pastoral lease land

2. Lessees could be required to prepare a pest management operational plan for pastoral lease lands they manage. Such plans could be prepared in consultation with the Department of Conservation, especially if public land administered by the Department, is or could be, affected by wilding tree spread.

3. LINZ could work with EECA, regional councils and energy companies (e.g. Meridian's Bioenergy division) to develop local biomass markets to significantly reduce the costs of removing dense stands of wilding conifers in some locations

4. Where pastoral lease land is affected by wilding conifers originating from Crown legacy plantings, options 1 & 2 from section 17.6.1 could be relevant

17.7.2 Wilding conifers on land being freeholded through tenure review

Issue

The Parliamentary Commissioner for Environment observed that the tenure review process has treated the management of wilding conifers inconsistently. In some cases their presence on land being freeholded has been ignored, while in others wilding conifers are to be managed (Section 11).

Options for land being freeholded through the tenure review process (one or all are possible)

1. The new landowner could be required (via a covenant or equivalent provision) to control wilding trees.

2. The new landowner could be required to prepare a wilding conifer management plan that includes a detailed implementation programme to be followed

3. Where part of the land is affected by wilding conifers originating from Crown legacy plantings, options 1 & 2 from 17.6.1 could be relevant

17.7.3 Wilding conifers on land allocated to the Department of Conservation through the tenure review process

Issue

Some of the land being allocated to the Department of Conservation as part of the tenure review process contains wilding conifers (and other pest species) at various densities. Funding allocated for controlling pest species on this land (including wilding conifers and rabbits) is probably not sufficient, especially as rabbit numbers are increasing (Section11)

Options

1. The Ministry of Agriculture and Forestry and Department of Conservation could work together to seek additional funding for the control of wilding conifers (and other pest species) on land transferred to the Department of Conservation via the tenure review process

2. The Department of Conservation could work with EECA, regional councils and energy companies (such as Meridian's Bioenergy division) to develop local biomass markets to significantly reduce the costs of removing dense stands of wilding conifers in some locations

17.8 Central government policy relating to carbon management

Issues

1. There is a potential conflict between Government policies that encourage the planting of new plantation forests using introduced conifer species (to reduce government's liabilities under the Kyoto Protocol) and actions to reduce the extent and impacts of wilding conifers.

2. While the Emissions Trading Scheme (ETS) relies on strategies and plans prepared under the Biosecurity Act and Resource Management Acts to address externalities (e.g. the risk of wilding conifer spread), those plans and strategies were prepared when the context was different and so do not consistently address environmental externalities as potentially envisaged by the ETS. As a consequence many landowners with wilding conifer stands that meet the definition of a post-1989 forest can register those stands to gain carbon credits without obligations for managing subsequent wilding conifer spread.

3. Landowners with large tracts of wilding conifers that meet the definition of a post-1989 forest could register part of the area of qualifying wildings to earn funding to manage the entire area of wildings. Management could include removals and containment (with buffers and species changes). There is, however, no requirement that the money earned from registering the wilding conifers in the ETS would be used in this way

4. Where forests are registered for the Permanent Forest Sink Initiative (PFSI) (thereby obtaining credit for carbon sequestration via Assigned Amount Units (AAUs)), there are no

requirements that such registration shall not be contrary with provisions in Resource Management Act plans and/or regional pest management strategies. As with the ETS there is no requirement for those gaining AAUs to manage any subsequent wilding conifer spread.

5. Post-1989 forests of *Pinus contorta* (an "unwanted organism" under the Biosecurity Act) can be registered under the ETS for carbon credits (NZU's) (Sections 6.1, 12)

6. The ability for landowners to obtain carbon credits under the Emissions Trading Scheme (via New Zealand Units (NZUs)) and the Permanent Forest Sink Initiative (via AAU's), and the associated liability if the forests are removed, creates a further disincentive for landowners to control wilding conifers (in addition to the costs of control) (Section 12.1)

7. Owners of forests registered under the ETS or PFSI are fully liable under those schemes if there is a fire or other catastrophic loss. Because of this, those involved in the forestry industry would be likely to oppose a potential externalities levy based on withholding a portion of the carbon credits.

Options (one or more are possible)

1. Territorial local authorities could be encouraged to assess the adequacy of their district plans to provide the safeguards envisaged by the ETS and amend their plans if appropriate

2. Regional councils could be required (via national policy direction) to assess the adequacy of their regional pest management strategies to provide the safeguards envisaged by the ETS and amend their strategies if appropriate

3. The eligibility of forests established from wilding conifers to gain carbon credits (NZUs or AAU's) under either the ETS or the PFSI could be removed.

4. The eligibility of post-1989 forests of an "unwanted organism" under the Biosecurity Act (*Pinus contorta*) to gain carbon credits (NZUs or AAU's) under either the ETS or the PFSI could be removed

5. Owners of post 1989 wilding conifer forests could be required to submit a management plan that sets out a programme for removing the wilding conifers and replacing them with less spread-prone species before their wilding conifer forest can be registered under the ETS. Progress on plan implementation could be reported at the same time as other ETS reporting

6. The Forest Act regulations associated with the Permanent Forest Sink Initiative could be amended so that forests being registered are required to be consistent with provisions in the relevant Resource Management Act plans and regional pest management strategies (as is required for ETS registered forests)

7. Withhold, as an externalities levy, a portion of the carbon credits assigned to stands of spread-prone conifers under the ETS or PFSI and invest it within a contestable wilding conifer management fund. If adopted it would be appropriate for this to be on a sliding

scale, rewarding those landowners/ land occupiers that site, design and manage their forests to minimise the risk of wilding conifer spread. For such a levy to be accepted by the forestry industry it would probably be necessary to reduce liabilities where there is a fire and/or provide a forest insurance programme

17.9 Central government policy affecting the species and locations planted

Issues

1. Recent changes to the New Zealand Building Code relating to the mechanical stress grading of sawn timber for use in house construction mean that radiata pine grown in many parts of the South Island does not reach a sufficiently high grade for it to be sold for use in New Zealand house construction (Section 10). Another change allows untreated Douglas fir to again be used in most timber-framed homes. These changes (alongside some actual and potential disease risks for radiata pine) provide a strong incentive for South Island growers to plant Douglas-fir, either by changing species after harvesting or growing Douglas fir in new locations.

2. The ETS and the PFSI (with their associated carbon credit systems) are highly likely to encourage landowners to plant new areas for forestry purposes. Such new areas are likely to include inland eastern South Island locations which can be highly vulnerable to invasion by wilding conifers (Refer 4.2).

3. The ETS and PFSI encourage species that can be managed on long rotations as this reduces liabilities associated with clearance. Douglas fir is well suited as a long rotation species and it can be selectively logged while leaving a growing forest. However, Douglas fir is more spread-prone than radiata pine, and can successfully establish in relatively intact indigenous grasslands and shrublands as well as beech forests where there are canopy gaps or canopy thinning (Refer 2.1.4, 4.1).

4. While the wilding conifer calculator in the proposed NES on plantation forestry could identify new plantations that require district council consent (with opportunities to require that certain mitigation measures be implemented), this mechanism would not be available for replanting (including sites where the species is changed to one that is more spread-prone) or for non-plantation plantings (e.g. shelterbelts).

Options (one or all are possible)

1. Regional and district councils could provide guidance to landowners and land managers on the risks of wilding conifer spread, potential consequences, and management regimes that could minimise risks. In the South Island this guidance could focus on Douglas fir given the current trends and issues, but may need to address other species if circumstances change

2. District plans could include planting standards for introduced tree species based on the application of a modified wilding tree risk calculator (Section 5)

3. An accord, equivalent to the Clean Streams Accord, could be developed between the forestry industry, Local Government New Zealand (on behalf of councils), Ministry of Agriculture and Forestry, Department of Conservation and LINZ. The purpose of this accord would be to develop protocols for the effective prevention and management of wilding conifer spread from planted forests

4. See 17.17 Research

17.10 Resource Management Act standards, policy statements and plans

17.10.1 Proposed National Environmental Standard for Plantation Forestry

Issues

1. The proposed NES for plantation forestry (Section 6.5.1) requires councils to use the wilding tree risk calculator to assess new plantings, but not for replanting after harvesting. While replanting has been excluded because it is considered to be an existing land use under s10A of the Resource Management Act, a strong argument could be made that where the species is changed so that the **effects** of the activity are different, then it is no longer an existing use. South Island forest replanting is likely to result in species changes with more areas being planted in species with a higher risk for producing wildings (Section 10).

2. The proposed NES for plantation forestry does not specifically address the management of wilding conifers originating from planted forests.

Options (one or more are possible)

1. The NES for plantation forestry could require councils to use the wilding tree risk calculator for replanting where there is a species change.

2. The proposed NES could provide guidance and/or direction about the management of wilding conifers originating from planted forests

3. See option 17.9.3

17.10.2 Resource Management Act plans

Issues

1. There are variations in how district plans treat planting using introduced conifer species (Refer 7.1.2, Appendix 7). Some eastern South Island plans do not contain provisions controlling the planting of introduced conifer species that have a high risk of spreading and some have provisions relating to one or several of the species responsible for wilding conifers.

Options (both are possible)

1. District plans applying to areas that are vulnerable to the spread of wilding conifers could include provisions (where they do not already do so) restricting /controlling the planting of introduced conifer species that have a high risk of spreading

2. Refer option 17.9.3

17.11 Regional pest management strategies and plans

Issues

1. There are variations in how regional pest management strategies (RPMS) address wilding conifers (Refer 7.1.1 and Appendix 6). This can lead to inconsistent outcomes associated with the implementation of national policy (e.g. emissions trading scheme) and management by national agencies (e.g. administration of pastoral leases)

2. Biosecurity Act requirements for cost-benefit analyses and opposition to the inclusion of species used for commercial production purposes within regional pest management strategies (even with carefully prescribed rules) restricts the extent to which regional councils can effectively control wilding spread from introduced conifer species

Options

1. Refer to 17.18 National Co-ordination options

2. Statutory national direction for regional pest management strategies could be provided using the national policy direction or the national pest management plan provisions in the Biosecurity Law Reform Bill 2010

3. See option 17.9.3

17.12 Relationships between central and local government policies

Issue

1. The priorities of central government land management agencies can be different to those of regional councils. Central government agencies are concerned that during a time of funding cuts that a future requirement (in the Biosecurity Law Reform Bill 2010) that they be bound by the good neighbour provisions in regional pest management strategies might adversely affect their existing or proposed land/ecosystem and pest management programmes (e.g. a requirement to spend more on rabbit control may reduce funding for the control of wilding conifers and other plant pests)

Options (one or both are possible)

1. Regional councils could liaise closely with central government land management agencies to: determine Crown priorities for pest management and negotiate an agreed approach

17.13 Funding

17.13.1 Central and regional government

Issues

1. Crown funding for wilding conifer control is severely constrained and may be further reduced. This limits the extent of wilding conifer control that can be undertaken and can limit the effectiveness of at least some control operations

2. In 2004 the Department of Conservation requested up to $5.3 million annually until 2014 (Parliamentary Commissioner for the Environment 2009) for wilding conifer control based on the Department's South Island wilding conifer strategy. It received only 10% of the funding requested ($555,000)

3. Public agencies have insufficient funding for effective long-term control of wilding conifers as required to protect and restore environmental values and to act as a good neighbour in protecting adjacent private land/economic values.

4. Funding for the Department of Conservation and other central government agencies is continuing to be cut

5. Regional councils in some of the regions where wilding conifers are a problem provide little or no resources for wilding conifer control/management

Options (All are possible)

1. The Ministry of Agriculture and Forestry, Ministry for the Environment, the Department of Conservation and Land Information New Zealand could prepare a combined proposal for central government funding as in the recommended national wilding conifer strategy

2. Funding proposals could include an education component that emphasises the importance of receiving sufficient funding to complete a long-term control programme

3. The recommended national wilding conifer strategy (Refer 16, 17.18) could identify generic and/or specific priorities for wilding conifer control/ management on public lands and possibly those of other tenures. The setting of national priorities may help ensure that public money is being used most effectively and could also contribute to proposals for additional funding. Existing programmes should, however, be maintained as discontinuation part way through a programme would waste the investment already made

17.13.2 Other parties

Issues

1. Individual properties can be either or both a source of wilding conifers and a recipient of wilding conifer spread from other properties. There is no effective [national] mechanism to address **funding** for managing externalities associated with wilding conifer spread

2. Landowners and land occupiers, especially those with extensive areas of marginal lands, often have insufficient funding to effectively control wilding conifers on land they own/occupy

3. Community trusts can have difficulty accessing funding which limits their ability to effectively control wilding conifers and their sources. There are risks that funding for follow-up for an already controlled area or for completing control in a single area may not be available in a timely way. This can threaten the viability of work already done

4. The requirement for multiple funding applications and the sometimes onerous auditing requirements can impose substantial burdens on community groups involved in wilding conifer control

Options (all are possible)

1. Where wilding conifers threaten biodiversity values landowners could apply to the Biodiversity Condition Fund or Nga Whenua Rahui (for Maori land) for funding for wilding conifer control

2. Where wilding conifers affect biodiversity and/or surface waters (by decreasing water yields) landowners and community groups may be able to apply to their district and/or regional council for funding assistance including rate relief

3. Section 17.6 contains options for legacy plantings and their associated wilding progeny

4. Options for assisting community trusts to obtain funding in a timely way could be investigated as part of the process for preparing a national strategy for wilding conifers (Refer 16, 17.18). This could include an assessment of the auditing requirements and ways these could be made less (financially) onerous for community groups

5. Working with the joint working group (of funding agencies, tangata whenua, industry and community members) that is to be set up under section 4.3 of the Ministry of Agriculture and Forestry's Pest Management National Plan of Action. The Group is to investigate co-ordinated funding and how collectives for pest management can be more easily formed and operated. It will also look at reducing duplication in reporting; streamlining application processes; and making it easier to fund large projects from multiple sources of funds

17.13.3 Cost –effective tools

Issues

1. The costs of key control tools (helicopters and fuel) are high and have risen faster than inflation

2. The very high costs associated with effectively removing dense mature infestations can mean that funding can not be obtained for the control of these areas even if they are continuing to cause ongoing wilding conifer problems

3. Department of Conservation research on cost-effective methods for wilding conifer control (and work to operationalise this research) may be threatened by restructuring and funding reductions.

Options (all are possible)

1. Researchers, central government agencies, and operators continue to investigate and further develop lower cost control methods

2. The proposed "integrated pest management toolbox" as proposed in section 3.1 of the Ministry of Agriculture and Forestry's Pest Management National Plan of Action could provide a framework for storing and communicating information about cost-effective wilding conifer control methods

17.14 Capacity

Issues

1. Department of Conservation restructuring may remove the jobs of some of the staff involved in pest (including wilding conifer) management thereby reducing the Department's capacity to control wilding conifers on lands it manages

2. Where a wilding conifer problem has been left on a property for many years, control today can be beyond the capacity of the current owner/occupier

Options (all are possible)

1. Landowners could utilise the "integrated pest management toolbox" as proposed in section 3.1 of the Ministry of Agriculture and Forestry's Pest Management National Plan of Action

2. Central, regional and local government could encourage more members of the community to become involved in wilding conifer control programmes. As volunteers are only permitted to use some control methods and in some locations, professionals would still be required for much of the control work

3. Local work schemes (with appropriate training and supervision) may be able to undertake some wilding conifer control

17.15 Perception

17.15.1 Decision-maker perceptions

Issues

1. While the most efficient time to address the spread of wilding conifers is the initial spreading stage when plants are small and densities are low, the public and decision-makers may not perceive that there is a problem. If action is delayed (as often happens) control becomes far more difficult and costly

2. When there are no visible tall conifers decision-makers can perceive there is no problem and so no funding is needed. This can limit the availability of funding for early control of wilding conifer spread ("Stitch in Time Saves Nine") and for follow-up control after the initial major control operations

3. Successful control operations mean there is no wilding conifer problem to see and so it can be difficult to demonstrate what has been done to build support for ongoing funding for surveillance and follow-up control of new growth.

4. Beliefs that long-term benefits (of effective control) should be discounted at an inappropriately high rate are contrary to the logic of early control ("Stitch in Time Saves Nine")

5. The financial implications of New Zealand's Kyoto Protocol commitments means that carbon sequestration is likely to be seen by many decision-makers as more important than wilding conifer control

Options (all are possible)

1. Develop an across-agency public education programme that emphasises the benefits of early action for wilding conifers and other pest plants. The framework for this could be developed as part of a national wilding conifer strategy (Section 17.18)

2. Comparisons of the cost-effectiveness of different scenarios for wilding conifer control could use a lower discount rate (e.g. equal to the current cost of money rather than an arbitrary 10%)

3. Develop an advanced visualisation tool that could spatially show changes over time in a particular landscape given certain environmental parameters and assumptions about different introduced conifer species and wilding conifer spread

17.15.2 Landowner perceptions

Issues

1. Effective wilding conifer management in an area may require co-ordinated management by the affected land owners/managers. Where one or more landowners decline to be involved, the effectiveness of those participating may be reduced. This impact on overall

effectiveness is most likely where the non-participating landowner has mature wilding conifers in high-risk locations for spreading

2. Landowners can be reluctant to spend money controlling wilding conifers when they consider that the actions of others (e.g. past Crown plantings of conifers) caused the problem

3. Landowners may be reluctant to spend money controlling wilding conifers if they think their stand has potential to earn ETS credits and/or be used for bioenergy

4. Landowners can see opportunities under the New Zealand ETS to encourage wilding spread to avoid the more capital intensive conifer planting programmes

5. Landowners can be suspicious of funding assistance that is tied to some type of council covenant securing public investments (a major concern can be a perception that there may be a requirement for future public access)

6. There can be a reticence by some landowners to undertake early control when seedlings are small and scattered ("Stitch in Time Saves Nine").

Options (all are possible)

1. See 17.15.1 *Decision-maker perceptions*, options 1 and 2

2. See 17.6 legacy plantings (and their associated wilding progeny) options

3. Regional councils could provide clear documentation for landowners about the benefits and obligations associated with receiving financial assistance (using public money)

4. See 17.8. options for Carbon Management

17.15.3 Public perception, preferences and values

Issues

1. Pest plants are not seen as a major problem by many.

2. Studies have shown that when the public are informed about the potential impacts of wilding conifers, especially on ecological values and ecosystem services, they are more likely to support expenditure for appropriate wilding conifer management/ control

Option (both are possible)

1. A recommended national wilding conifer strategy (Section 17.18) could provide the framework for developing an across-agency public education programme that informs the public about the scale of the wilding conifer problem, the existing and potential impacts of wilding conifers, what needs to be done to address these impacts, and the benefits of early action.

2. See 17.15.1 *Decision-maker perceptions*, option 3

17.16 Monitoring and reporting wilding conifer extent and density

Issues

1. There are inaccuracies and gaps with the South Island wilding conifer partial database compiled in 2007 and there is no funding for refining and updating this database. There is no North Island wilding conifer database.

2. An electronic version of the decision support system for identifying the risk of wilding conifer spread (DSSb) (Ledgard 2008) has been used to assess the risk of wilding conifer establishment for each point in an assessed landscape. Further work is required to improve the utility of predictions of future risk and expand the geographic range of areas assessed. This will require: refinement of the underlying decision support system, model refinement on smaller and better datasets; improving the main datasets used for wider application of the model; and scenario testing of alternatives. There is no funding allocated for this work.

3. A lack of consistent methodology for monitoring hinders effective reporting of the scale of the problem and control successes

Options (both are possible)

1. Options for establishing a long-term comprehensive database of wilding conifer extent and density could be addressed as part of the recommended national wilding conifer strategy. This could be within the context of the National Weeds Distribution Database. Funding for this would need to be addressed in the strategy

2. The recommended national wilding conifer strategy (Sections 16, 17.18) could include wilding conifer monitoring and reporting standards to: assist with the maintenance and refinement of the national database on wilding conifers; and improve planning and reporting of the scale of the wilding conifer problem and successes.

17.17 Research

Issues

1. The funding and implementation of key research priorities identified in section 13.2 would provide opportunities for improving environmental outcomes (as they relate to actual and potential wilding conifer spread) and wilding conifer management

2. While the development and use of sterile conifers could in the long-term lead to a substantial decrease the problem of wilding conifers, there are considerable challenges. Support from the public and Forest Stewardship Council would be required

Option

1. The recommended national wilding conifers strategy (Refer 16, 17.18) could include a research "strategy" that identifies research priorities and potential funding. (Section 13 Research –contains a list of potential future research options). Important areas of future research include: improving the modelling of future risk of wilding conifer spread; development of an economic model of nett present liability to provide guidance on the type and timing of management interventions; understanding the potential spread and impacts of Douglas fir in New Zealand ecosystems and opportunities for prevention and mitigation of potential adverse effects; the development of a visualisation tool that can display sequentially likely changes over time in a landscape (See 17.15.1); and the development of hybrids and sterile trees (especially for Douglas fir) to reduce the long term risks of wilding conifer spread.

17.18 National strategy and co-ordination

Issue

A number of people involved with wilding conifer management have expressed concern about the absence of a national strategy for wilding conifer management. Suggested purposes for such a strategy include: raising the profile of the problem; guiding priority setting for management; facilitating co-ordination between agencies; and improving funding opportunities and continuity (Section 16).

Options (one of the following approaches could be selected)

1. A non-statutory national strategy could be prepared for wilding conifer management. Matters that could be addressed include the administration and implementation of the Biosecurity and Resource Management Acts; priorities for management on lands of different tenures; education; research and monitoring; and co-ordination across legislation and between organisations. Specific topics could include standards for monitoring and reporting; and the management of Crown/regional council legacy plantings and their wilding conifer offspring. This could be implemented using a variety of statutory (e.g. a national pest management plan) and non-statutory mechanisms as appropriate. The formal processes required for developing and implementing statutory tools would still need to be followed

2. A statutory national pest management plan (as provided for in the Biosecurity Law Reform Bill (2010)) could be prepared for wilding conifers. This plan would address those introduced conifer species which have the greatest risk of spreading. In the case of species used for production purposes, the plan would need to clearly distinguish between appropriate plantings and those organisms that are "wildings". Other "wrong place" pests, including deer and trout, are controlled in inappropriate places by national instruments. Matters that could be addressed in the national pest management plan include: responsibilities, co-ordination and collaboration, funding, regional pest management strategy/plan provisions,

and monitoring and reporting. Specific topics could include standards for monitoring and reporting; and the management of Crown legacy plantings and their wilding conifer offspring.

18 Recommendations

This report has analysed and evaluated a wide range of topics relevant to wilding conifer management in New Zealand. Section 17 summarised many of the issues and identified a range of options that could be considered. Case study analyses identified useful lessons to inform future management.

The following recommendations were initially developed by the report's author and were subsequently endorsed with minor modifications at the September 2011 meeting of the Wilding Conifer Management Group. The main addition by the group was to expand the first recommendation to include a commitment to produce a national management strategy by the end of 2012.

18.1 Specific recommendations

1. ***That a non-statutory national strategy be prepared for wilding conifer management. The issues and options (section 17) provide a framework for the strategy.***
   Matters that should be addressed include:
   - g. ***The administration and implementation of the relevant legislation and national policy;***
   - h. ***Economic aspects including levels and sources of funding;***
   - i. ***Priorities for management on lands of different tenures;***
   - j. ***Education, research and monitoring (including standards for assessing and reporting change);***
   - k. ***Co-ordination across legislation and between organisations:***
   - l. ***The management of Crown/regional council/private legacy plantings and their wilding conifer offspring.***

   This strategy could be implemented using a variety of statutory and non-statutory mechanisms.

Rationale

Effective long-term control of wilding conifers often requires co-ordinated multi-agency/ multi-landowner management, especially where the wilding conifers (and their source populations) are spread across lands of different tenures. Individual agencies and landowners addressing wilding conifers only on lands they administer/manage can find that their isolated efforts are undermined by reinvasion. While co-ordination takes place at a number of locations, this often depends on the initiative and impetus provided by particular individuals. To obtain the benefits from a more consistent and co-ordinated approach, it is recommended that a non-statutory strategy for wilding conifers be prepared. The first step in preparing such a strategy would be to identify national objectives and principles. Specific matters to be addressed in the strategy include the items listed in (a)-(f) above plus other matters identified in section 17.

The recommendation for a national strategy is consistent with feedback from a number of people involved with wilding conifer management who have expressed a strong desire for national co-ordination via a national strategy for wilding conifer management. A national strategy could:

- Raise the profile of wilding conifer issues with government and within the wider community;
- Assist with assessing and prioritising funding bids on an on-going basis (or for a defined period);
- Help achieve consistency in approach to wilding conifers in central government policy making and regional pest management strategies and district plans;
- Assist with priority setting for wilding conifer management across lands of different tenures.

A non-statutory strategy is recommended as this provides a framework for addressing a wide range of matters, including those that extend beyond the scope of statutory documents and processes under the Biosecurity or Resource Management Acts. A National Pest Management Strategy (NPMS) under the Biosecurity Act 1993 is not favoured at this time because such strategies are slow and expensive to produce[8] and because their primary benefits (the ability to exercise coercive powers) are not necessary for the issues relevant to wilding conifers.

Another benefit of the non-statutory approach is that it provides an opportunity to evaluate different broad strategies for wilding conifer management in different contexts. For example, it may be possible to evaluate whether it would be more cost-effective in the long-term to remove source populations (and particularly dense wilding conifer infestations rather than leaving these areas) and focusing on distant wilding conifer spread. Many of the worst wilding conifers infestations are associated with early/ legacy plantings, often by Crown agencies. Today the cost of removing these source populations and the associated wilding spread can be very high. Leaving these areas sees costs of removal rise, often exponentially. Existing funding streams are not sufficient to remove these areas.

Once prepared a variety of tools could be used for implementing a non-statutory strategy. This could include statutory mechanisms following processes set out in the appropriate legislation. There are also a wide variety of potential non-statutory tools available.

2. ***That the Ministry of Agriculture and Forestry be the lead agency for preparing this strategy given its biosecurity functions, including the administration of the Biosecurity Act.***

Rationale

Potential agencies for leading the preparation of such a strategy seem to be limited. By definition, the development of a national strategy needs to be coordinated at a national level. While the agency responsible for leading the preparation of a national strategy could be one of the four government departments involved in the New Zealand Wilding Conifer Management Group (Ministry of Agriculture and Forestry, Department of Conservation, LINZ, Ministry of Defence), the Ministry of Agriculture and Forestry seems to be most appropriate given its biosecurity functions including its roles in administering the Biosecurity Act. The Ministry also has the lead government

[8] It is acknowledged that some simplification of process for preparing pest management strategies is included in the Biosecurity Law Reform Bill 2010 currently before Parliament.

role for plantation forestry and administers the Forests Act and the Climate Change Response Act. The other three Departments primarily manage wilding conifers on lands they administer (although Department of Conservation does some wilding conifer management on lands of other tenures on behalf of councils and landowners and LINZ administers pastoral leases). The general consensus of those consulted seems to be that with its lead role for Biosecurity, the Ministry of Agriculture and Forestry would be ideally placed to lead the preparation of such a strategy.

This is consistent with the Pest Management: National Plan of Action (PMNPA), which confirms the Ministry's role as overall leader for pest management systems including:

- Promoting alignment of pest management activities within the whole biosecurity systems
- Facilitating the development and alignment of national pest management plans
- Promoting public support for pest management
- Facilitating communication, co-operation and co-ordination of those involved in pest management to enhance effectiveness, efficiency and equity

It is important to note, however, that while the Ministry should, consistent with the PMNPA, lead strategy development, *implementation* of the strategy would need to be a broad, multi-party responsibility. In that context MAF is likely to have a limited role beyond monitoring strategy implementation and perhaps some residual Crown liabilities. Again, this is consistent with the leadership functions described in the PMNPA, which also sees a regional leadership role for regional councils and functions for many other organisations to be carried out in respect of particular organisms, processes, pest pathways and places.

3. ***That stakeholder involvement in the strategy preparation process be formalised using a stakeholder forum and/or advisory group. The existing New Zealand Wildling Conifer Management Group could provide an appropriate stakeholder forum.***

Rationale
Many agencies, organisations, landowners and land managers have a role to play in the effective long-term management of wilding conifers in New Zealand. It is, therefore, recommended that a stakeholder forum and/or advisory group be actively involved in the preparation of the recommended national wilding conifer management strategy. Such involvement helps to ensure that the concerns and interests of the relevant parties are appropriately addressed as part of the strategy preparation processes and the developed strategy has widespread support. Such support will substantially increase the likelihood that the strategy will be implemented by the various parties.

One option for the stakeholder forum is the existing New Zealand Wildling Conifer Management Group. This Group has the advantage that it already exists with an extensive mailing list, a website and organisational structure. The Group has changed its role from one of research oversight to policy guidance and liaison. Disadvantages of using this Group are that people nominate themselves and those attending meetings do not necessarily have the authority to speak on behalf of or to commit their organisations. This later problem may be able to be addressed through the Memorandum of Understanding that those organisations providing funding to the Group sign each year.

A key component of the strategy will be the sources and availability of funding, especially for control and monitoring. As such it may be useful to involve Treasury, the Ministry for the Environment and/or Parliamentary Commissioner for the Environment in the process of strategy preparation. The latter two organisations are suggested because of their potential roles in national state of environment monitoring and reporting.

4. ***In the context of developing and implementing recommendation 1, it is recommended that:***
    a. ***An accord be developed between the forestry industry, Local Government New Zealand (on behalf of councils), Ministry of Agriculture and Forestry, Department of Conservation and LINZ. The purpose of such an accord would be to develop protocols for the effective prevention and management of wilding conifers spread from planted forests. Arising out of the national strategy, it may also be appropriate to develop other accords.***

Rationale

Factors pointing to the utility of an accord with protocols to prevent and manage wilding conifers spread from planted forests include:

- Interest by the plantation forestry sector to address wilding conifer risk in a responsible way that avoids the potential costs and uncertainty associated with different Resource Management Act (RMA) plan provisions
- Prevention of new sources of wilding conifer spread is an important component of long-term national wilding conifer management
- Increased planting of Douglas fir (with its changed wilding conifer risk profile (section 2.4), especially in the South Island (section 10)
- The Resource Management Act existing use rights for land mean that it is very difficult for councils to address wilding conifer risk management for areas that are being replanted (after felling an existing introduced conifer crop)

A recent example of sector-agency accord is the Clean Streams Accord 2003 for the dairy industry (http://www.mfe.govt.nz/issues/land/rural/dairying-accord-may03.pdf). Potential other accords with the same or different parties may be identified as part of the process for preparing the recommended national strategy for wilding conifers.

b. ***Further work be undertaken to determine the level of funding required to effectively control wilding conifers (in priority areas); how costs should be apportioned between different parties in different situations; and potential sources of additional funding.***

Rationale

While this report was prepared using a variety of information (published and unpublished reports and papers, interviews and the internet) it was not possible to confirm the level of funding required to effectively control wilding conifers in different contexts. It was, however, clear that the costs of control per hectare vary considerably depending on a variety of factors including density and size of

the conifers, accessibility, terrain, visibility of the conifers (e.g. conifers in tall scrub are more difficult to find than conifers in grassland) and stage in the control cycle (e.g. initial control versus follow-up after recent control).

To make meaningful comparisons it would be necessary to have more detailed information on costs per hectare for different types of control in different contexts. It is unlikely that current agency costs data would be sufficiently detailed and consistent to permit such an analysis at this time. Given the complexity of factors affecting costs it may be necessary to design an "experiment" that facilitated the assessment of the contribution of different factors in different contexts. Such an "experiment" would have to be very carefully designed for the results to have any predictive power. In general terms per hectare control costs are very high and can be difficult to accurately predict where there are dense mature stands of wilding conifers and the original source populations. Costs associated with control over larger areas with low densities of wilding conifers are much lower and more easily estimated.

The effective implementation of this recommendation also requires an assessment of control requirements for different areas. Such information is available for some locations (e.g. the Department of Conservation has detailed operational plans for controlling wilding conifers on some of the lands it administers). In other areas such detailed information (on the location of source and wilding populations, their density, species and age) is not available. Such information would be needed before the level of funding required for control could be determined. Consistent monitoring and reporting standards (as proposed in recommendation 1(d)) would greatly assist those trying to aggregate data about wilding conifers on lands of different tenures within a region.

To move beyond the status quo is likely to require additional funding. In the current economic funding such funding is likely to be difficult to find. It will be necessary to investigate potential alternative sources of this funding.

c. ***Options for funding for the removal of problem Crown legacy plantings and the associated wilding conifer spread be investigated as a matter of good faith and prudent long-term environmental management***

Rationale

Previous central government plantings of some of the more spread-prone introduced conifer species have resulted in considerable wilding conifer spread. Examples include plantings:

- For erosion control/revegetation (e.g. Mid-Dome in Southland, Kaweka Ranges and various south Marlborough catchments);
- For plantation forestry research/trials (e.g. Hamner and Craigeburn Forests in Canterbury); and
- To mitigate lake-shore erosion and landscape impacts associated with hydro-electric power development (e.g. Lake Pukaki area).

The removal of these source populations, the associated wildings and their progeny is now very expensive and usually beyond the scope of current agency/ landowner budgets. Progress has been made in some locations. In most cases the costs associated with removing the source plantings and

the dense older wildings typically requires funding beyond that which agencies or agency-community trusts have been able to access (e.g. Mid Dome Wilding Trees Charitable Trust (Appendix 11.5), and the Waimakariri Ecological Landscape Restoration Alliance).

In the context of Crown legacy plantings and their progeny there are a number of precedents where the Crown has funded environmental restoration activities needed to remedy problems caused by earlier Crown actions. Examples include: Crown funding for the restoration of Lake Taupo and the Rotorua Lakes, and for re-diverting the Kaituna River back into Maketu Estuary. The principles behind these programmes, and Crown acceptance of an obligation to remedy past environmental damage resulting from its actions, should be further investigated in the context of current and future funding for the management of past Crown plantings of spreading wilding conifers (and their consequential progeny).

d. ***Options for redressing competing objectives that may hinder the appropriate and timely removal of wilding conifers on private land be further investigated, including those associated with the Emissions Trading Scheme***

Rationale

Competing government objectives can hinder the appropriate and timely removal of wilding conifers on private lands. One such "conflict" is between objectives that seek the removal of wilding conifers to reduce adverse impacts on biodiversity and other values (especially on public conservation lands) versus maximising carbon storage under the Emissions Trading Scheme (ETS). In this context individual landowners may choose to retain their wilding conifers and gain financial reward by registering the affected areas under the ETS. Taking this course of action may result in considerable wilding conifer infestation of downwind public conservation lands and/or lands owned by others.

There is no prohibition on landowners registering areas of wilding conifers (for carbon credits (NZUs) under the ETS, as long as this is not contrary to provisions in RMA plans or a pest management strategy prepared under the Biosecurity Act. In practice, existing RMA plans and regional pest management strategies (RPMSs) are unlikely to have much impact on wilding conifers (except for contorta pine outside of Canterbury and dwarf mountain pine in Southland). As a consequence most landowners with wilding conifer stands that meet the definition of a post-1989 forest will be able to register those stands to gain carbon credits without any obligation to manage subsequent wilding conifer spread. It may also be possible for landowners to register their wilding conifers under the Permanent Forest Sink Initiative (PFSI) which has no requirements for consistency with the Biosecurity and Resource Management Acts no requirement to manage any subsequent wilding conifer spread.

With many landowners unable to afford removing existing wilding conifers, especially if they have been left for some years, registration for carbon credits may be a very attractive option. Once registered, a landowner may find there will be a significant financial penalty to pay to remove a wilding conifer forest. This penalty would be a major disincentive for removal. There is a risk that the effectiveness of community programmes to remove wilding conifers from some areas may be compromised if a number of landowners have registered their wilding conifers under the ETS or the PFSI.

It is possible to use funds obtained from an area of wilding conifer "forest" registered under the ETS or PFSI to remove other areas of wilding conifers and to contain and then gradually replace an existing stand with species less likely to spread. While at least one property is using funds in this way as part of a long-term plan, there is no requirement for landowners registering wilding conifers in the ETS or PFSI to prepare and implement a long-term plan to manage spread. In addition some landowners who may have been prepared to remove wilding conifers (especially if resources had been available) may now register their wilding conifer forest in the ETS or PFSI. Thus the Government policy may have an unintended consequence of creating an incentive for the retention of wilding conifers.

e. ***National policy direction [9] provide guidance about the scope of "good neighbour rules" in regional pest management plans in respect of plant species whose seed can be transported long distances***

f. ***National policy direction provides guidance on how regional pest management strategies should treat species that are a resource in one place and a pest in another (e.g. introduced conifer species planted and managed for timber, and red deer farmed for many products; both are controlled in other locations)***

Rationale
The Biosecurity Law Reform 2010 (once enacted) will provide a new tool – that of national policy direction under the Biosecurity Act. National policy direction should facilitate consistency between councils in how they address certain topics.

It would be logical for the "good neighbour rules" for plant species with seed that can be transported long distances, to be different to the rules applying to species whose seed is generally transported over much shorter distances. As seed from the former can easily be transported over regional boundaries a consistent national approach would be appropriate to ensure that the required control is effective and reasonable.

National direction would also assist councils to develop appropriate RPMS provisions for species that are both a pest and a resource. Several plant and animal species fall into this category. National direction should assist councils to develop appropriate controls that minimise adverse impacts (usually on natural systems and other land owners) while still providing economic opportunities

g. ***Options for providing support for collective community action in respect of wilding conifer management be investigated as proposed in the National Pest Management Plan of Action***

Rationale
Community trusts can have difficulty accessing funding which limits their ability to effectively control wilding conifers and their sources. There are risks that funding for follow-up for an already

[9] Under the Biosecurity Act (as is being provided for under Biosecurity Law Reform 2010 and proposed in the National Pest Management Plan of Action)

controlled area or for completing control in a single area may not be available in a timely way. This can threaten the viability of work already done. In addition the requirement for multiple funding applications, and the sometimes onerous auditing requirements, can impose substantial burdens on community groups involved in wilding conifer control

The collective action section (4.3) of the Pest Management National Plan of Action proposed that a joint working group (of funding agencies, tangata whenua, industry and community members) be established. The purpose of this group would be to investigate co-ordinated funding and how collectives for pest management could be more easily formed and operated. It is proposed that the group would also look at reducing duplication in reporting; streamlining application processes; and making it easier to fund large projects from multiple sources of funds. While this proposal applies to pests generally, it is particularly relevant for wilding conifers where removal costs (especially of mature dense stands) can be very expensive and follow-up surveillance and control is needed to remove plants initially missed and plants that have germinated from the soil seed-bank.

h. ***Tools be developed for increasing public and decision-maker awareness of the risks and impacts of wilding conifers, management needed and what has already been achieved***

Rationale

When there are no visible tall conifers the public and decision-makers can perceive there is no problem (and so no funding is needed). In other words other projects have higher priority. This can limit the availability of funding for early control of wilding conifers spread (Stitch In Time Saves Nine") and for follow-up control after the initial major control operations. Conversely, when the trees are left to spread, control is then considered too difficult.

One potential way to increase public and decision-maker awareness of the potential impacts of wilding conifers under different management scenarios would be to develop an advanced visual tool that could spatially show changes over time in a particular landscape given certain environmental parameters and assumptions about different introduced conifer species and wilding conifer spread.

19 References

Agee JK 1998. Fire and pine ecosystems. In: Richardson DM ed. Ecology and biogeography of *Pinus*. Cambridge, Cambridge University Press. Pp. 193-218.

Allen RB, Lee W 1989. Seedling establishment microsites of exotic conifers in Chionochloa rigida tussock grassland, Otago, New Zealand. New Zealand Journal of Botany 27(491-498).

Baillie BR 2011. Freshwater ecology in plantation forest streams. Ecology in the Heartland, New Zealand Ecological Society Conference 28 August-1 September 2011, Rotorua.

Bannister MH 1958. Evidence of hybridization between *Pinus attenuata* and *P. radiata* in New Zealand. Transactions of the Royal Society of New Zealand 85: 217-225.

Beauchamp RR 1962. Regeneration of Mackenzie trees. Tree Grower 4(67-8). Cited in Hunter & Douglas 1984.

Bell B, Cudby C, Yap M 2009. Biodiversity valuation model- a technical manual for MAF BNZ, Nimmo-Bell & Company Ltd. 84 p.

Beneke U 1962. The weed potential of lodgepole pine. Tussock Grasslands and Mountain Lands Institute Review No 13. Cited by Harris Consulting 2000.

Brockerhoff EG, Hoffmann JH, Roques A 2004. Is biological control an option for the management of wilding pines (*Pinus* spp) in New Zealand? In: Hill RL, Zydenbos SM, Bezar C ed. Managing wilding conifers in New Zealand: present and future. Proceedings of a workshop held in conjunction with the annual conference of the New Zealand Plant Protection Society. Chateau on the Park, Christchurch, August 2003. New Zealand Plant Protection Society: Pp. 65-78.

Brockerhoff EG, Ecroyd CE, Leckie LC, Kimberley MG 2003. Diversity and succession of vascular understory plants in exotic Pinus radiata plantation forests in New Zealand. Forest Ecology and Management 185: 307-326.

Brown K, Moore S, Udy G 2010. Wilding conifer management Mount Richmond Forest Park issues and options. Nelson, Department of Conservation Nelson/Marlborough Conservancy. 24 p.

Buchanan J 1869. Sketch of the botany of Otago. Transactions and Proceedings of the New Zealand Institute 1: 181-212. (cited in Walker et al. 2009a)

Cattaneo M 2002. Effects of microsite characteristics, competition and grazing on *Pinus contorta* and *Pseudotsuga menzies*ii seedling establishment. Unpublished M.Sc. Thesis. School of Forestry, University of Canterbury, Christchurch. 154 p.

Cheeseman T 1925. Manual of the New Zealand flora Wellington, Government Printer. 1163 p.

Chevasse GCR 1979. Spread of exotic tree species into native forests. Forest Research Institute Report 131. Rotorua, Forest Research. 49 p.

Chu-Chou M; Grace L 1987. Mycorrhizal fungi of *Pseudotsuga menziesii* in the South Island of New Zealand. Soil Biology and Biochemistry 19: 243-246

Cleary EA 1982. Ecological aspects of Douglas-fir invasion of mountain beech forest on Ben Lomond Reserve, Queenstown, New Zealand. Unpublished M.Sc. Thesis. University of Otago, Dunedin (cited in Ledgard 2005).

Clout MN, Gaze PD 1984. Effects of plantation forestry on birds in New Zealand. Journal of Applied Ecology 21: 795-815.

Crozier ER, Ledgard NJ 1990. Palatability of wilding conifers and control by simulated sheep browsing. In: Beasett et al ed. Alternatives to the chemical control of weeds. Proceedings of the International Conference, Forest Research Institute, Rotorua, New Zealand, 25-27 July 1989. Forest Research Institute Bulletin No 155: Pp. 139-143.

Cunningham A 1974. Headwaters of the Tutaekuri catchment. Study of an erosion problem in Hawke's Bay. New Zealand Forest Service Technical Paper No 62. Rotorua, New Zealand Forest Research Instsitute. 59 p.

Cunningham A 1979. A century of change in the forests of the Ruahine Range, North Island, New Zealand: 1870-1970. New Zealand Journal of Ecology 2: 11-21.
Cunningham A, Austin N 1974. Wakarara erosion control programme, 1974-1978. Internal report prepared for the New Zealand Forest Service. Palmerston North, New Zealand Forest Service. 16 p.
Davis M 2008. Mycorrhizas: a context for species siting and management? New Zealand Journal of Forestry 53(1): 12-15.
Davis M, Coker G, Howell C, Henley D 2011. Establishment of *Pseudotsuga menziesii* and *Pinus nigra* seedlings in *Kunzea ericoides* and *Leptospermum scoparium* shrubland communities. New Zealand Journal of Ecology 35(3).
Davis MR 1994. Topsoil properties under tussock grassland and adjoining pine forest in Otago, New Zealand. New Zealand Journal of Agricultural Research 37: 465-469.
Davis MR, Lang MH 1991. Increased nutrient availability in topsoils under conifers in the SOuth Island high country. New Zealand Journal of Forestry Science 21(2/3): 165-179.
Davis MR, Grace LJ, Horrell RF 1996. Conifer establishment in South Island High Country: influence of mycorrihizal inoculation, competition removal, fertiliser application, and animal exclusion during seedling establishment. New Zealand Journal of Forestry Science 26(3): 380-394.
Day C, Ledgard NJ 2009. Wakatipu wilding conifer strategy. Prepared for Queenstown Lakes District Council. Queenstown and Christchurch, Go-Green Consulting and Scion. 100 p.
Dehlin H, Peltzer DA, Allison VJ, Yeates GW, Nilsson C, Wardle DA 2008. Tree seedling performance and below-ground properties in stands of invasive and native tree species. New Zealand Journal of Ecology 32(1): 67-79.
Department of Conservation 2009. Department of Conservation Hawke's Bay Area wilding pine operational plan. Internal Report. Napier, Hawke's Bay. 48 p.
Department of Conservation 2010. Hawke's Bay Area Wildling Pine Operational Plan 2009-2014. Napier, Department of Conservation. 53 p.
Department of Conservation, Land Information New Zealand, South Island High Country Federated Farmers, Environment Canterbury 2010. Canterbury wilding conifer strategy 2010-2015. Christchurch, Environment Canterbury. 28 p.
Dick MA, Horgan GP, Bain J 2004 Pitch canker- the threat to New Zealand. In: Hill RL, Zydenbos SM, Bezar C ed. Managing wilding conifers in New Zealand: present and future. Proceedings of a workshop held in conjunction with the annual conference of the New Zealand Plant Protection Society. Chateau on the Park, Christchurch, August 2003. New Zealand Plant Protection Society: Pp. 79-95.
Dick RD 1976. Amuri Range region- Report of a land inventory survey and mention of some land management problems. Unpublished report of North Canterbury Catchment Board, Christchurch. Cited in Hunter & Douglas 1984.
Dickie I 2011. Do beech and pine share mycorrhizal partners? A scientific journey. Indigena February 2011. Pp 4-8.
Dickie IA; Bolstridge N , Cooper JA, Peltzer DA 2010. Co-invasion by Pinus and its mycorrhizal fungi. New Phytologist 187(2): 475-484.
Duncan MJ 1996. A methodology for identification of areas vulnerable to flow reductions because of afforestation. NIWA Christchurch Consultancy Report No CRC60512. Cited in Environment Canterbury Regional Council 2011. Christchurch.
Duncan MJ 2000. Review of the Duncan model for assessing the impacts of afforestation on water yield. Canterbury Regional Council unpublished technical report U00/48. Cited in Environment Canterbury Regional Council 2011.
Duncan MJ 2003. Clarification of the effect of vegetation change on water yield Prepared for Environment Canterbury unpublished technical report U03/81. Cited in Environment Canterbury Regional Council 2011.
Duncan RP, Williams PA 2002. Darwin's naturalisation hypothesis challenged. Nature: 608-609.

Dungey HS, Low CB, Ledgard NJ, Stovold GT 2011. Alternatives to *Pinus radiata* in the New Zealand high-country: early growth and survival of *P. radiata, P. attenuata* and their F1 hybrid. New Zealand Journal of Forestry Science 41: 61-69.
Environment Canterbury Regional Council 2011. Canterbury Natural Resources Regional Plan. Chapter 5: water quantity. http://ecan.govt.nz/publications/Plans/nrrp-chapter-5-cover-main-text-operative-110611.pdf , accessed 15 June 2011, Environment Canterbury Regional Council. 214 p.
Fahey B, Duncan M, Quinn J 2004. Impacts of forestry. In: Harding J, Mosley P, Pearson C, Sorrell B ed. Freshwaters of New Zealand. Wellington, New Zealand Hydrological Society. Pp. 33.1-33.16.
Fahey B, Davie T, Stewart M 2011. The application of a water balance model to assess the role of fog in water yields from catchments in the east Otago uplands, South Island, New Zealand . Journal of Hydrology (New Zealand) 50(2): 279-292.
Fairweather JR, Swaffield SR 2002. Public perception of natural character and implications for the forest sector. New Zealand Journal of Forestry 47(2): 24-30.
Floate M 1994. Review of South Island high country land management issues. New Zealand Journal of Ecology 18: 69-81.
Forest Research Institute 1998. Report on the impacts of wilding conifers. Meeting the requirements of section 72(1)(c) of the Biosecurity Act 1993. Prepared for Canterbury Regional Council. Christchurch. 7 p.
Fowler SV, Syrett P, Hill RL 2000. Success and safety in the biological control of environmental weeds in New Zealand. Austral Ecology 25: 553-562.
Froude VA 2002. Biological control options for invasive weeds of New Zealand protected areas. Science for Conservation 199. Wellington, Department of Conservation. 68 p.
Froude V 2011(a). Wilding conifer status report project - preliminary discussion paper for the New Zealand Wilding Conifer Management Group. Pacific Eco-Logic, Bay of islands. 7 p.
Froude VA 2011(b) Wilding conifers in New Zealand.: Beyond the status report. A report for the Ministry of Agriculture and Forestry. Pacific Eco-Logic, Bay of Islands. 43p.
Froude VA, Rennie HG, Bornman JF 2010 The nature of natural: defining natural character for the New Zealand context. New Zealand Journal of Ecology 34(3).
Gilmore J W 1958. Chlorosis of Douglas fir. New Zealand Journal of forestry 7:94-106.
Gous SF, Watt MS, Richardson B, Kimberley MO 2010. Herbicide screening trial to control dormant wilding *Pinus contorta, P. mugo,* and *Pseudotsuga menziesii* during winter. New Zealand Journal of Forestry Science 40: 153-159.
Grove P 2010. Monitoring wilding conifer spread in the Canterbury High Country- 2010 progress report. Internal Environment Canterbury Report. 3 p.
Haggerhall CM 2001. Consensus in landscape preference judgements. Journal of Environmental Psychology 21: 83-92.
Harding M 2001. South Island Wilding Conifer Strategy. http://www.doc.govt.nz/publications/conservation/threats-and-impacts/weeds/south-island-wilding-conifer-strategy/. Christchurch, Department Of Conservation.
Harris Consulting 2000. Meeting the requirement of the Biosecurity Act 1993. Economic evaluation of options for regional pest management strategies for plant pests. Round II. Report for Canterbury Regional Council. Christchurch. 26 p.
Hewson D 2009. Wilding conifer management plan for the Broad Stream Area. Report prepared for the Waimakariri Ecological and Landscape Restoration Alliance (WELRA) & World Wildlife Fund for Nature (WWF). 35 p.
Hock BK, Langer ER, Ledgard NJ, Manley B 2001. Economic and social impacts of land use change in the unimproved pastoral lands of the New Zealand high country: A methodological case study. Forest Research Bulletin No 120. Rotorua, Research F. 71 p.

Hogg JT, Garrett JW 1975. The eradication of *Pinus contorta,* Waiouru Military Reserve. Unpublished report to the Rangitikei-Wanganui Catchment Board. Cited in Hunter & Douglas 1984.

Howell C 2008. Consolidated list of environmental weeds in New Zealand. Department of Conservation Research & Development Series 292. Wellington, Department of Conservation. 42p.

Howell CJ, Sawyer JWD 2006. New Zealand naturalised vascular plant checklist. Wellington, New Zealand Plant Conservation Network.

Hunter G, Douglas M 1984. Spread of exotic conifers on South Island rangelands. New Zealand Journal of Forestry 29: 78-96.

Huston M, Smith T 1987. Plant succession: life history and competition. American Naturalist 130: 168-198.

Jorgensen H 2010. NOBANIS-Invasive alien species fact sheet-*Pinus mugo*. From: Online Database of the North European and Baltic Network on Invasive Alien Species-NOBANIS www.nobanis.org Date of access 6 December 2011.

Kerr GN, Sharp BMH 2007. The impact of wilding trees on indigenous biodiversity: a choice modelling study. Research Report No. 303. Lincoln, Agribusiness and Economics Research Unit Lincoln University. 41 p.

Klijzing K 2002. A study of Douglas fir (*Pseudotsuga menziesii*) dispersal into native beech (*Nothofagus* spp) forest and microsite factors predisposing seedling establishment. Unpublished Bachelor of Tropical Forestry Thesis. Larenstein College, Netherlands (cited in Ledgard 2005).

Lamb RJ; Purcell AT 1990. Perception of naturalness in landscape and its relationship to vegetation structure. Landscape and Urban Planning 19: 333-352.

Land Information New Zealand, Department of Conservation, Ministry of Agriculture & Forestry 2008. Report of Government objectives for the South Island High Country for the three years ended 30 June 2008. Wellington, Land Information New Zealand.

Langer ER 1993. Delayed germination of introduced conifers in Canterbury Unpublished Forest research contract report Christchurch. 17 p.

Le Maitre DC, Versfield DB, Chapman RA 2000. The impact of invading alien plants on surface water resources in South Africa, a preliminary assessment. Water SA 26: 397-408. Cited in Simberloff et al. 2010.

Ledgard NJ 1989. The spread of Douglas fir into mountain beech forest on Burnt Face, Craigeburn Forest Park. Prepared for the Department of Conservation, Canturbury Region. Christchurch, Forest Research Institute. 4 p.

Ledgard NJ 1990. The spread of introduced conifers at Mt Aurum Station: background, present situation and management options. Prepared for the Department of Conservation. Christchurch, Forest Research Institute.

Ledgard NJ 1993a. Future prospects for conifer spread from Hamner Forest. New Zealand Forest Research Institute Contract Report FR208. Prepared for David Poole, Forestry Manager, Southern Region, Carter Holt Harvey Forest Ltd. Rangiora, New Zealand Forest Research Institute. 6 p.

Ledgard NJ 1993b. Conifer spread in the Amuri Range area. Range, composition, likelihood of future spread and management options. New Zealand Forest Research Contract Report FRI 0118/33. Rangiora, New Zealand Forest Research Ltd. 23 p.

Ledgard NJ 1996. Operational plan for the control and management of introduced conifers in the Red Hills, Gordons Range and Beebies Ridge area of Mt Richmond Forest Park. Report prepared for Department of Conservation, Nelson-Marlborough Conservancy. Rangiora, New Zealand Forest Research Institute. 15 p.

Ledgard NJ 2001a. The spread of lodgepole pine (*Pinus contorta* Dougl.) in New Zealand. Forest Ecology and Management 141: 43-57.

Ledgard NJ 2001b. Report on the management of introduced conifers in the Beebys Ridge Area of Mt Richmond Forest Park. A Forest Research contract report prepared for Department of Conservation, Nelson. Christchurch, Forest Research. 8 p.
Ledgard NJ 2002. The spread of Douglas-fir into native forests. New Zealand Journal of Forestry 47(2): 36-38.
Ledgard NJ 2004a. A strategy for control of wilding conifers in North Marlborough. A Forest Research Contract Report for Marlborough District Council. Christchurch, Forest Research. 32 p.
Ledgard NJ 2004b. Wilding conifers - New Zealand history and research background. In: Hill R, Zydenbos SM, Bezar C ed. Proceedings of a workshop held in conjunction with the annual conference of the New Zealand Plant Protection Society, Chateau on the Park, Christchurch, August 2003. New Zealand Plant Protection Society: Pp. 1-25.
Ledgard NJ 2004c. A strategy for control of wilding conifers in South Marlborough. A Forest Research Contract Report Prepared for Marlborough District Council. Christchurch, Forest Research. 45 p.
Ledgard NJ 2004d. The rise and fall of introduced conifers on Molesworth Station. http://www.wildingconifers.org.nz/index.php?option=com_content&view=article&id=13:molesworth-a-case-study&catid=7:case-studies-2007&Itemid=19 Accessed 6 December 2011.
Ledgard NJ 2005. Higher altitude forestry in Canterbury, Otago and Southland. Issues and opportunities. A Scion Contract Report prepared for Ministry of Agriculture and Forestry. Christchurch, Ensis Scion. 54 p.
Ledgard NJ 2006a. The spread of introduced conifers on Molesworth Station. A review of the present situation and future control options. An Ensis Contract Report Prepared for the Department of Conservation. Christchurch, Ensis Scion. 46 p.
Ledgard NJ 2006b. Douglas-fir wilding spread and mitigation of risk. New Zealand Douglas-fir Cooperative Report No 50 Ensis Scion.
Ledgard NJ 2008. Assessing risk of wilding spread. New Zealand Plant Protection 61: 91-97.
Ledgard NJ 2009a. Wilding control. Guidelines for the control of wilding conifers. Christchurch, New Zealand Forest Research Institute. 52 p.
Ledgard NJ 2009b. Wilding conifers in the Hawke's Bay Region and in the upper catchment of the Rangitaiki River. Report prepared for Hawke's Bay Regional Council Envirolink Project 736 HBRC Wilding Control. Christchurch, Scion New Zealand Forest Research Institute Ltd. 30 p.
Ledgard NJ, Baker GC 1997. Management options for introduced trees on Ruataniwha Farm, aound Lakes Tekapo, Pukaki and Ruataniwha, and within the Tekapo, Pukaki and Ohau Rivers. Prepared for Land Information New Zealand. Rangiora, New Zealand Forest Research Institute. 14 p.
Ledgard NJ, Langer ER 1999. Wilding prevention. Guidelines for minimising the risk of unwanted wilding spread from new plantings of introduced conifers. Christchurch, Forest Research. 21 p.
Ledgard NJ, Palmer D 2004. Issues concerning wilding spread from recent Douglas fir plantings in the upper Mataura catchment Southland. A Forest Research contract report prepared for Environment Southland. 32 p.
Lucas D, Head J 1995. Indigenous ecosystems: an ecological plan structure for the Lakes District. A report to the Queenstown Lakes District Council. Christchurch, Lucas Associates.
Mark AF, Dickinson KJM 2003. Temporal responses over 30 years to removal of grazing from a mid-altitude snow tussock grassland reserve, Lammerlaw Ecological Region, New Zealand. New Zealand Journal of Botany 41: 655-668.
Mark AF, Dickinson KJM 2008. Maximising water yield with indigenous non-forest vegetation: a New Zealand perspective. Frontiers in Ecology and the Environment 6(1): 25-34.
McFayden REC 1998. Biological control of weeds. Annual Review of Entomology 43: 369-393.
McGlone MS 2001. The origin of the indigenous grasslands of southeastern South Island in relation to pre-human woody vegetation. New Zealand Journal of Ecology 25(1): 1-15.

McKelvey 1995. Steepland forests. Christchurch, Canterbury University Press,. 295 p.
McNeil S 2008. Wilding conifer risk mapping in the Canterbury Region: a modelling approach. Landcare Research Contract Report LC0809/000. Prepared for Scion and the South Island Wilding Conifer Management Group. Lincoln, Landcare Research. 25 p.
Meurk CD, Hall GMJ 2006. Options for enhancing forest biodiversity across New Zealand's managed landscapes based on ecosystem modelling and spatial design. New Zealand Journal of Ecology 30(1): 131-146.
Meurk CD, Norton DA, Lord JM 1989. The effect of grazing and its removal from grassland reserves in Canterbury. In: Norton DA ed. Management of New Zealand's natural estate. Occasional Publication No. 1. Christchurch, New Zealand Ecological Society. Pp. 72-75.
Mid Dome Wilding Trees Charitable Trust, Environment Southland, Department of Conservation, Land Information New Zealand 2010. Memorandum of understanding for the control of wilding trees, Mid Dome, Northern Southland. Date 15 September 2010. Pp. 4.
Mid Dome Wildling Trees Charitable Trust 2008. 12 year wilding tree eradication programme. A blueprint for ecological recovery, Mid Dome Wildling Trees Charitable Trust. 21 p.
Miller JT, Ecroyd CE 1987. Introduced forest trees in New Zealand: recognition, role and seed source. *Pinus contorta* Loudon - contorta pine. Forest Research Institute Bulletin No 124. Rotorua, New Zealand. 12 p.
Miller JT, Knowles FB 1994. Introduced forest trees in New Zealand: recognition, role and seed source. 14. Douglas-fir, *Pseudotsuga menziesii* (Mirbel) Franco. Forest Research Institute Bulletin. Rotorua, New Zealand. 38 p.
Ministry of Agriculture and Forestry 2011. Pest management national plan of action. Wellington, Ministry of Agriculture and Forestry. 38 p.
Mosley MP 1999. Identification of areas in Canterbury sensitive to flow reductions due to afforestation. Prepared for Canterbury Regional Council unpublished technical report U99/54. Cited in Environment Canterbury Regional Council 2011.
Newton BM, Fairweather JR, Swaffield SR 2002. Public perceptions of natural character in New Zealand: wild nature versus cultured nature. New Zealand Geographer 58(2): 17-29.
New Zealand Forest Owners Association 2011. New Zealand plantation forest industry facts and figures. Wellington, New Zealand Forest Owners Association, Ministry of Agriculture & Forestry. 45 p.
New Zealand Government 2008. National Plant Pest Accord.
North H, Ledgard NJ 2005. Modelling wilding conifer spread and control. Landcare Research Contract Report LC 04/05. Prepared for Environment Canterbury. Christchurch, Landcare Research. 27 p.
North H, Bartie P, Ledgard NJ 2007. Wilding conifer project report, July 2007: Objective 1 (mapping /risk assessment). Report for the New Zealand Wildling Conifer Management Group. 3 p.
Norton DA, Ledgard NJ 2007. Past, present and future status of wilding conifers, Mt Dewar Station, and future control costs. Christchurch, School of Forestry University of Canterbury and ENSIS. 33 p.
Old A 2003. Report on exotic wilding tree spread within defined areas of the Canterbury high country. Report No. U03/55. Christchurch, Environment Canterbury. 16 p.
Owen SJ 1998. Department of Conservation strategic plan for managing invasive weeds. Wellington, Department of Conservation. 86 p.
Parliamentary Commissioner for the Environment 2009. Change in the high country: environmental stewardship and tenure review. Wellington, Parlimentary Commissioner for the Environment. 92 p.
Paul T, Ledgard NJ 2011. Impacts of wilding conifers and their control on grassland and shrublands in New Zealand. Ecology in the Heartland Conference, 28 August -1 September 2011, Rotorua, New Zealand Ecological Society.

Paul THS, Ledgard NJ 2009. Vegetation succession associated with wilding conifer removal. New Zealand Plant Protection 62: 110-119.
Paul TSH, Ledgard NJ 2008. Effect of felled wilding pines on plant growth in high country grasslands. New Zealand Plant Protection 61: 105-110.
Pawson SM, Ecroyd CE, Seaton R, Shaw WB, Brockerhoff EG 2010. New Zealand's exotic plantations as habitats for threatened indigenous species. New Zealand Journal of Ecology 34(3): 342-355.
Pearce AJ, Rowe LK, O'Loughlin CL 1984. Hydrology of mid-altitude tussock grasslands, upper Waipori catchment: II Water balance, flow duration and storm runoff. Journal of Hydrology (New Zealand) 23: 60-72.
Radiata Pine Breeding Co 2003. Radiata pine wood density. RPBC Information Bulletin No 2.
Richardson DM, Higgins SL 1998. Pines as invaders in the southern hemisphere. In: Richardson DM ed. Ecology and biogeography of *Pinus*. Cambridge, Cambridge University Press. Pp. 450-473. Cited in Simberloff et al. 2010.
Richmond C, Froude V, Fenemor A, Zuur B 2004. Management and Conservation of natural waters. In: Harding J, Mosley P, Pearson C, Sorrell B ed. Freshwaters of New Zealand. Wellington, New Zealand Hydrological Society. Pp. 44.1-44.19.
Roche M 1990. History of New Zealand forestry. Wellington, GP Books.
Rogers GM, Walker S, Lee WG 2005. The role of disturbance in dryland New Zealand: past and present. Science for Conservation 258. Wellington, Department of Conservation.
Rogers GM, Walker S, Basher LM, Lee WG 2007. Frequency and impact of Holocene fire in eastern South Island, New Zealand. New Zealand Journal of Ecology 31(2): 129-142.
Seaton R 2011. The conservation values of planatation forests for New Zealand's indigenous birds. Ecology in the Heartland, New Zealand Ecological Society Conference 28 August-1 September 2011, Rotorua.
Simberloff D, Nunez MA, Ledgard NJ, Pauchard A, Richardson DM, Sarasola M, Van Wilgen B, Zalba SM, Zenni RD, Bustamante R and others 2010. Spread and impact of introduced conifers in South America: lessons from other southern hemisphere regions. Austral Ecology 35: 489-504.
Slow LJ 1954. Douglas fir regeneration on the Kaingaroa Plains. New Zealand Journal of Forestry 7(1): 83-89.
Smith W 1903. Plants naturalised in the County of Ashburton. Transactions and Proceedings of the New Zealand Institute 36: 203-225.
Standish RJ, Sparrow AD, Williams PA, Hobbs RJ 2009. A state and threshold model for the restoration of abandoned farmland in New Zealand. In: Hobbs RJ, Suding KN ed. New models for ecosystem dynamics and restoration Society for Ecological Restoration International.
Stephens RTT 2004. Wilding conifer control: how important is it relative to other conservation actions? In: Hill RL, Zydenbos SM, Bezar C ed. Managing wilding conifers in New Zealand: present and future. Proceedings of a workshop held in conjunction with the annual conference of the New Zealand Plant Protection Society. Chateau on the Park, Christchurch, August 2003. New Zealand Plant Protection Society: Pp. 27-39.
Storer AJ, Wood DL, Gordon TR 2004. Could biological control of wilding pines increase the potential for damage by the pitch canker pathogen? In: Hill RL, Zydenbos SM, Bezar C ed. Managing wilding conifers in New Zealand: present and future. Proceedings of a workshop held in conjunction with the annual conference of the New Zealand Plant Protection Society. Chateau on the Park, Christchurch, August 2003. New Zealand Plant Protection Society.
Thomson GM 1922. The naturalisation of animals and plants in New Zealand. Cambridge, Cambridge University Press.
U S Forest Service 1995. Silvics of forest trees of the United States. Agriculture Handbook No 271. Washington, US Department of Agriculture. Cited in Ledgard 2001.

Van der Putten WH, Bargett RD, de Ruiter P, Hol WHG, Meyer KM, Bezemer TM, Bradford MA, Christensen S, Eppinga MB, Fukami T and others 2009. Empirical and theoretical challenges in aboveground-belowground ecology. Oecologia 161: 1-14.

Walker S, Wilson JB, Lee WG 2004. Pre-settlement woody vegetation of Central Otago. New Zealand Journal of Botany 42: 613-46.

Walker S, Cieraad E, Monks A, Burrows L, Wood J, Price R, Rogers GM, Lee B 2009a. Long-term dynamics and rehabilitation of woody ecosystems in dryland South Island, New Zealand. In: Hobbs RJ, Suding KN ed. New models for ecosystem dynamics and restoration, Society for Ecological Restoration Internation. Pp. 99-111.

Walker S, King N, Monks A, Williams S, Burrows L, Cieraad E, Overton JM, Price R, Smale M 2009b. Secondary woody vegetation patterns in New Zealand's South Island dryland zone. New Zealand Journal of Botany 47(367-393).

Wardle P 1985. Environmental influences on the vegetation of New Zealand. New Zealand Journal of Botany 23: 773-788.

Wardle P 1991. The vegetation of New Zealand. Cambridge, Cambridge University Press.

Webb CJ, Skyes WR, Garnock-Jones PJ 1988. Flora of New Zealand Volume IV: naturalised pteridophytes, gymnosperms, dicotyledons. Christchurch, DSIR Botany Division. 1365p.

Wildlands Consultants 2011. Review of *Pinus contorta* management in the East Taupo, Upper Mohaka, Rangitaiki, and Waipunga catchments. Contract Report No. 2613; Prepared for Bay of Plenty Regional Council. Rotorua, Wildland Consultants. 54 p.

Williams PA 1983. Secondary vegetation succession on the Port Hills Banks Peninsula, Canterbury, New Zealand New Zealand Journal of Botany 21: 237-247.

Wilmshurst JM, Anderson AJ, Higham FG, Worthy TH 2008. Dating the late prehistoric dispersal of Polynesians to New Zealand using the commensal Pacific rat. Proceedings of the National Academy of Sciences of the United States of America 105(22): 7676-7680.

Woods D 2007. Wilding conifer management report for Flock Hill Station, Waimakariri Basin, Canterbury. Report prepared for Environment Canterbury. Christchurch. 71 p.

Woods DC 2004. The highs and lows of wilding conifer control operations: the good, the bad and the ugly! In: Hill RL, Zydenbos SM, Bezar C ed. Managing wilding conifers in New Zealand: present and future. Proceedings of a workshop held in conjunction with the annual conference of the New Zealand Plant Protection Society. Chateau on the Park, Christchurch, August 2003. New Zealand Plant Protection Society Inc: Pp. 55-63.

Yeates GW, Sagar S 1998. Comparison of soil microbial properties and fauna under tussock-grassland and pine plantations. Journal of the Royal Society of New Zealand 28: 523-535.

Yeates GW, Sagar S, Daly BK 1997. Soil microbial C, N and P and microfaunal populations under *Pinus radiata* and grazed pasture land use systems. Pedobiologia 41: 549 565. Cited in Yeates & Sagar 1998.

20 Appendices

20.1 Appendix 1: Terms of Reference

Part 1

History

- Establishment of wilding conifers in New Zealand;
- How the wilding conifer issue has evolved over time;
- Major species involved and their differing spread capability;

Current impacts

- Extent of wilding conifer infestation;
- Nature and scale of the issue at the present time on different land ownership (i.e. DOC, LINZ and private land);
- The type and extent of impacts (considering different environments, land uses and conifer species);

Current management

- The extent to which management outcomes are clear and being met;
- Current management and funding arrangements, including identifying the cost of existing programmes
- Management approaches , including how different land owners manage wildings (i.e. DOC, LINZ and private);
- Range of control methods and examples of land management (and the associated costs) that have effectively controlled wilding conifers on prone land and how this can be used to inform best practice;
- Current level of public awareness about the wilding conifer issue;
- Any barriers to effective wilding conifer control and management;
- Various aspects of national and regional legislation related to wilding conifers and how these interact, including Biosecurity Act, Resource Management Act, Emissions Trading legislation and Regional Pest Management Strategies.

Part 2

Future risk

- The likely future trends of spread and implications for land occupiers and funding;
- Related issues
- Links with other land use issues, such as the High Country tenure review process, high country pest management, and alternative approaches to sustainable and integrated land management practices on wilding conifer prone land;
- Other related issues that will support the work of the Wilding Conifer Management Group;

Opportunities to improve wilding conifer management

- Existing wilding conifer research and identify any gaps and future research priorities;
- Opportunities for more efficient use of existing funds and the case for increased public funding for wilding conifer control;
- ETS implications and future trends for land owners of pre-1990 and pot-1989 forest lands;
- Mechanisms to support collective action (groups of land occupiers working together) including the roles of agencies and land occupiers, and the interventions in the Pest Management National Plan of Action; and
- Any other opportunities to improve wilding conifer management in New Zealand

20.2 Appendix 2: National extent and relative density of Pinus contorta and Douglas fir: as estimated by a process led by B Kappers of the Department of Conservation

(Details in section 3.2; maps supplied by B Kappers of the Department of Conservation)

20.3 Appendix 3: Presence/ absence of four introduced conifer species by 10km2 grid squares over ten years prior to 2007 as estimated in a process led by Clayson Howell of the Department of Conservation

(Details in section 3.2; maps supplied by C Howell of the Department of Conservation)

20.4 Appendix 4: Wilding tree risk calculator

DSS 2 CALCULATING RISK OF WILDING TREE SPREAD INTO/WITHIN NEW SITES [1]
(Developed by Nick Ledgard**)**

(Select score applicable for each of the six categories)

1). SPECIES PROVIDING SEED SOURCE *(score for one species only)*
Spreading vigour varies with species

- Redwoods, Leyland cypresses, cedars and spruces — 0
- Radiata (*P. radiata*) and ponderosa (*P. ponderosa*) pine, Lawsons cypress (*C. lawsoniana*) — 1
- Muricata (P. *muricata*) and maritime (*P. pinaster*) pine and larches (*Larix* spp) — 2
- Corsican (*P. nigra*) and mountain/dwarf mountain (*P. uncinata/mugo*) pine — 3
- Douglas-fir (*Ps. menziesii*), Scots (*P. sylvestris*) and Lodgepole/contorta (*P. contorta*) pine — 4

Enter score (0, 1, 2, 3 or 4) here ☐

2). SITING OF SOURCE TREES [2, 3]
Source trees are on….

- Sites well sheltered from prevalent and strong winds — 0
- Flat sites (<10^0), partially exposed to strong/prevalent winds — 1
- Lea slopes where strong eddy gusts are likely — 2
- Flat sites (<10^0), fully exposed to strong/prevalent winds — 3
- *Either* elevated 'take-off' sites, (ridge-tops, or base of exposed slopes >10^0) *or* sloping land, fully exposed to strong/prevalent winds — 4

Enter score (0, 1, 2, 3 or 4) here ☐

3). SITING OF SAMPLE SITE RELATIVE TO SOURCE TREES
Location relative to seed-dispersing winds

- Up-wind relative to prevalent or strong winds (If upwind and >1km distant - score 0) — 1 (0)
- Subject to cross-winds and/or wind-eddies relative to prevalent or strong winds — 2
- Down-wind relative to prevalent and strong winds (often from N and W) — 3

Enter score (0/1, 2 or 3) here ☐

4). DISTANCE OF SAMPLE SITE FROM SOURCE TREES
Spread risk decreases with distance from seed source

- Greater than 5km — 0
- 1-5km — 1
- 200m – 1km — 3
- 0-200m — 4

Enter score (0, 1, 3 or 4) here ☐

5). GRAZING WITHIN SAMPLE AREA
Wilding establishment influenced by grazing (particularly with sheep)

- Intensive grazing on developed pasture — 0
- Regular mob stocking with sheep [4] — 1
- Semi-improved grazing (sheep/cattle)/ occasional mob stocking with sheep — 2
- Extensive grazing only [5] — 3
- No grazing — 4

Enter score (0, 1, 2, 3 or 4) here ☐

6). VEGETATION OF SAMPLE SITE *(if Douglas-fir involved see [6] below)*

Wilding establishment influenced by competition from existing vegetation

- Developed pasture, rank grass, closed canopy forest (no gaps) 0
- Shrubland/tussock/grassland with a continuous and heavy vegetation cover 1
- Forest/shrubland/tussock/grassland with few gaps 2
- Open forest and/or scattered patches of dense shrubland/tussock/grassland with many gaps 3
- Open slips/rockland and/or light, low-stature shrubland/tussock/grassland 4

Enter score (0, 1, 2, 3 or 4) here ☐

TOTAL SCORE: ☐

WHAT THE SCORE MEANS

1. A total score of **14** or more indicates a high risk of invasion by the assessed species onto the sample area.
2. If a score of '0' is obtained in any one category, the total score automatically becomes '0' (so there is no risk of wilding spread).

NOTES:

[1] **Multiple calculations:** As the above score sheet indicates, there are a range of factors influencing the risk of spread. The impact of these will vary from site to site, both relative to the seed source and to the land being sampled. Therefore, spread risk will need to be calculated not just once, but a number of times in order to accommodate the range of sites represented at the seed source and at the site being sampled.

[2] **Altitude:** The coning ability of some species drops off quickly with increasing altitude. Contorta and mountain pine will readily establish and cone above native treeline. Scots pine and Douglas-fir will establish at tree line. Corsican pine and Douglas-fir coning drops off quickly above 800 and 1100 m respectively – the limit for Scots pine coning is unknown. Radiata pine is a reluctant spreader above 6-700 m, except on the warmer sites. The altitudinal establishment and coning limits for muricata pine and larch are unknown.

[3] **Long distance spread:** This is likely if a score of 3 or 4 in 'Siting' (in 3) is followed by a 2 or greater in 'Vegetation' and 'Grazing' (in 5 & 6), especially if Douglas-fir, larch or Corsican, contorta, mountain or Scots pines are involved (all have light seed which is readily dispersed greater distances by wind).

[4] **Regular mob stocking:** If the pasture is only semi-improved and the seed rain is heavy, such as alongside mature conifers (particularly Corsican pine – the least palatable conifer), regular mob stocking may not prevent wilding establishment over the long term.

[5] **Light grazing:** This will reduce wilding establishment, but given enough time, some wildings will eventually grow to above browse height. Palatability of introduced conifers is (in decreasing order): radiata > ponderosa > contorta > larch > Scots pine > Douglas fir > Corsican pine.

[6] **Douglas-fir:** This species is more shade tolerant than the other common conifers. This species is more shade tolerant than the other common conifers. Therefore, it is more likely to invade under forest canopy gaps and within low-stature (<2m tall) shrublands.

20.5 Appendix 5: Expanded detail on the Biosecurity and Resource Management Acts

20.5.1 The Biosecurity Act 1993

The Biosecurity Act 1993 is the primary statute for addressing wilding conifers, especially outside of land is administered by Crown agencies. In addition to being responsible for the administration of the Biosecurity Act, the Minister has responsibility (s8) for providing for the coordinated implementation of the Act.

The purpose of Part 5 of the Act is to provide for the effective management or eradication of pests and unwanted organisms. Section 55 specifies that the management or eradication of pests must be in accordance with pest management strategies made in accordance with Part 5 of the Act. This section also requires each pest management strategy to specify which of the powers in Part 6 may be exercised during the implementation of the strategy. Those powers can only be exercised if they are specified in the strategy.

A minister or a person may prepare a proposal for a national pest management strategy (s56). A minister may notify such a proposal only if the minister is of the opinion:

- that the benefits would outweigh the costs;
- the net benefits of national intervention would exceed the benefits of regional intervention;
- where the strategy requires persons to directly meet the cost of implementation, either those persons contribute to the creation or exacerbation of the problem to be resolved by the strategy, or the benefits will outweigh the costs;
- each organism in the proposed strategy is able to cause a serious adverse and unintended effect for New Zealand for one or more of the following: economic well-being; viability of threatened species or the survival and distribution of indigenous plants and animals, or the sustainability of natural and developed ecosystems, ecological processes or biodiversity; soil or water quality; human health or enjoyment of recreational value of the natural environment; or relationship of Maori and their culture and traditions with the ancestral lands, waters, waahi tapu and taonga.

Before notification the Minister must also be of the opinion that the organisms (s57(2) are either:

- not known to be established or are of restricted distribution and abundance, but have the potential to cause significant economic loss and/or environmental degradation, and could be effectively managed or eradicated
- widely distributed and effective action would be impracticable without a national strategy; and the potential economic, social or environmental damage or loss of not taking action on a national basis would be significant

Any person may request that a minister whose responsibilities may be affected by an organism, notify a proposal for a national pest management strategy (s58). The Minister may refuse to notify such a strategy if certain circumstances apply (s 59). Section 60 specifies the general matters to be addressed in a national pest management strategy, while section 61 specifies funding matters to be addressed (including the rationale for the proposed allocation of costs). Section 62 sets out the notification process, while section 63 sets out the procedure for appointing a Board of Inquiry. Before the Minister recommends that there be In Order in Council for a national pest management strategy, the Minister must consider the report and recommendations from the Board of Inquiry and the CEO report on the Board's report. The Minister must also be satisfied (s69(2)) that the matters in section 57(1) have been addressed and that there is likely to be adequate funding to implement the strategy for five years or for the strategy duration (which it is shorter).

Specific measures to be addressed by a national pest management strategy are in section 69A. Section 69B identifies the purposes for rules that can be made in a national pest management strategy. Section 69D sets out the procedures for the Minister to exempt a person from specific rules in the strategy.

A regional council or any other person may prepare a proposal for a regional pest management strategy (RPMS) (s71). The regional council must notify such a proposal if it considers that (s72):

- the benefits of a regional pest management strategy for each organism covered would exceed the costs;
- the benefits of regional intervention exceed those of the individual intervention;
- where the strategy requires persons to directly meet the costs of implementation, the equivalent section for a NPMS applies;
- each organism in the strategy is capable of causing serious adverse and unintended effects in the region to one or more of the items listed for the equivalent section for a NPMS

Section 73 sets out RPMS consultation requirements (relevant ministers, local authorities, tangata whenua). Any other person can be consulted. Section 76 specifies general matters that are to be addressed in a proposed RPMS. Funding information requirements are specified in section 77. Sections 78-79 set out the procedures for notification, hearings and references to the Environment Court. Section 80A specifies detailed matters to be addressed, while section 80B sets out the purposes for rules. Section 80 D provides for a regional council to exempt a person from a rule requirement in the RPMS. Joint regional council pest management strategies are possible (s83).

Sections 83-89 apply to both national and regional pest management strategies. A management agency (for the purpose of a pest management strategy) can be a government department, regional council, local authority, or a body corporate. Within three months of a strategy being operational a management agency is to prepare an operational plan for the strategy's implementation (s85(1)). This plan is to be reviewed annually.

A national pest management strategy imposes costs and obligations on the Crown (s87(1)). All or part of a regional pest management strategy may apply to the Crown (via an Order in Council),

although the level of Crown costs and obligations depend on what is provided for in the Order in Council (s87(2)).

A pest management strategy ceases to have effect in certain situations (s88(2)). Reviews are provided for, including a mandatory five yearly review (s88). A proposal for review is notified and follows the processes used in the preparation of the strategy.

On the recommendation of a minister an Order in Council may impose a levy for the implementation of a pest management strategy. This is payable to the management agency. Procedures relating to levy imposition, fund management, auditing and disputes are addressed in sections 91-97. Section 97 addresses the funding of RPMS implementation through rates.

The national pest management strategy process has not yet been used for any plant species. Each regional council has prepared one or more (over time) regional pest management strategies. These strategies typically contain various provisions applying to a collection of plant and animal species. A number contain provisions applying to one (usually contorta pine) or sometimes more species of wilding conifer.

20.5.2 The Resource Management Act 1991

The purpose (s5) of the Resource Management Act is to promote the sustainable management of natural and physical resources. Section 6 lists a number of matters of national importance that all those exercising powers and functions under the Act are to recognise and provide for. Relevant section 6 matters are:

- Preservation of the natural character of the coastal environment, wetlands, rivers, lakes and their margins… (s6(a)
- Protection of outstanding natural features and landscapes…(s6(b)
- Protection of significant indigenous vegetation and significant habitats of indigenous fauna (s6(c))

Under section 7 all those exercising powers and functions under the Act are to have “particular regard to” the following matters that are relevant for wilding conifer management:

- The maintenance and enhancement of amenity values (s7(c))
- Intrinsic values of ecosystems (s7(d))
- Maintenance and enhancement of the quality of the environment (s7(f)

The Act provides a hierarchy of planning instruments. At the national level there are national policy statements and national environmental standards. Regional government prepares mandatory regional policy statements and regional coastal plans. Other regional plans are optional. Territorial authorities prepare mandatory district plans. Decisions on land use are primarily made at the district plan level although a regional policy statement can provide high-level guidance (e.g. identifying urban boundaries).

The process of plan preparation provides opportunities for public input into plan policies, rules and other mechanisms. In a district plan there is typically a mixture of district wide and “zone” specific rules applying to an area. Planning maps identify zones (or equivalent) and other spatially based attributes (e.g. significant sites for indigenous vegetation or wildlife habitat; outstanding natural

landscapes). There may also be specific rules and/or other provisions applying to these spatially based attributes.

Rules typically assign different types of activities or environmental effects, (or a combination of the two) into the following categories: permitted, controlled, restricted –discretionary, discretionary, non-complying and prohibited. Activities (or environmental effects) that do not meet the standards for permitted activities require a resource-consent. For controlled activities a council can not decline an application but can set conditions. Councils can decline applications for other categories of resource-consent application. With restricted discretionary activities a council restricts its discretion on the range of matters it can address to those specified in the relevant plan. Where an activity is non-complying a council may only give consent if it considers the impacts would be no more than minor and that the proposal would not be contrary to the objectives and policies in the relevant operative and/or proposed plan. No applications may be made for prohibited activities.

District councils are required to establish, implement and review objectives, policies and methods to achieve integrated management of the effects of the use, development and protection of land and other natural and physical resources. The primary way they do this is via district plans and their implementation. District plan preparation is typically a lengthy process involving both pre-formal consultation as well as clearly specified formal processes (s72-85, Schedule1). Sections 87-150 address resource consents, although not all of these sections are relevant to land use applications.

In the context of wilding conifer management, district plans can play a useful role in determining and regulating future land use. District plans can address matters such as:

- Using the wilding tree risk calculator (refer section 5 for further comment on the wilding tree risk calculator) to determine high risk situations for forestry plantations and other tree planting using introduced conifer species;
- Restricting or prohibiting the planting of species known to have a high spread risk in certain locations
- Addressing potential wilding conifer spread risk, impacts and management as part of the assessment process for relevant resource-consent applications

Regional councils can (via regional plans) control land use for the following purposes: soil conservation; maintenance and enhancement of water quality and quantity and aquatic ecosystems; and the avoidance and mitigation of natural hazards (s30). In the context of land use the regional council role is narrower than the district's role as the regional focus is the effect of land use on water and aquatic ecosystems.

20.6 Appendix 6: Key provisions relating to wilding conifer species in regional pest management strategies

Council and year of RPMS	Conifer species	Status in plan/ plan rules	Plan objectives	Council actions
Hawke's Bay 2006	*Pinus contorta*	Total control Owner responsibility throughout the region Unless an occupier has entered into a *Pinus contorta* control programme approved by Hawke's Bay Regional Council, the occupier shall destroy all *Pinus contorta* before hard seed production and prevent the movement of *Pinus contorta* (including seed and soil likely to contain seed from an infested site) An occupier may control *Pinus contorta* via a control programme approved by Council Where the occupier does not adhere to an approved control programme, direction may be issued for eradication /control (under s122 Biosecurity Act) On default Council may carry out the work and recover costs from the landowner	To contain *Pinus contorta* within known infested properties & reduce population within these Progressive control of *Pinus contorta* over time	Council may meet up to 50% of costs (maximum $3000) of *Pinus contorta* control on rateable land for approved control programmes DOC control of *Pinus contorta* under the Hawke's Bay Conservancy wilding pine strategy 1999 (now updated- (Department of Conservation 2010)) is an approved strategy under the RPMS
Waikato 2008	*Pinus contorta*	Containment pest plant- occupier control Occupier to destroy all *Pinus contorta* on land occupied No sale or propagation of *Pinus contorta*	Reduce the risk of spread and where practicable reduce infestations of *Pinus contorta* in forested areas Destroy all *Pinus contorta* plants outside production forestry (including all privately owned plantations)	Waikato Regional Council may undertake direct control of *Pinus contorta* in accordance with the RPMS and may do so with DOC or others WRC will monitor *Pinus contorta* in region
Bay of Plenty 2003-2008	Contorta pine	Progressive control pest plant (PCPP) Land occupiers shall destroy all PCPP unless	Reduce density and/or distribution with priority given to	Where control is part of an approved BOPRC programme (e.g.

Council and year of RPMS	Conifer species	Status in plan/ plan rules	Plan objectives	Council actions
		control is via an approved BOPRC programme No person shall move or interfere with any item used for monitoring or controlling/ eradicating any PCPP No person shall sell, display or propagate any PCPP	controlling isolated/ satellite populations	environmental programme, care group or community control programme) funding support is available Co-ordinate and support approved control programmes May undertake pest control Monitoring, investigations, publicity
Bay of Plenty 2011-2016 Draft	Contorta pine	Containment pest plant (CPP) Occupiers & landowners shall destroy all CPP No person shall move or allow to be moved any machinery etc. that is contaminated with any CPP No person shall sell, display or propagate any CPP	Reduce density and/or distribution of CPP to a level that can be sustained with minimal costs	Where control is part of an approved BOPRC programme (e.g. environmental programme, care group or community control programme) funding support may be available Co-ordinate and support approved control programmes May undertake pest control Monitoring, investigations, publicity
	Wilding pines (changed to wilding conifers?)	Restricted pest plants (RPP) No person shall move or interfere with any item used for monitoring or controlling/ eradicating any RPP No person shall sell, display or propagate any RPP	Bay of Plenty residents and community groups understand the impacts of RPP, prevent their spread & voluntarily participate in activities that contribute to the management of impacts	Funding may be available where control is part of an approved council programme
Horizons MW 2007	Contorta pine	Two regimes: • Control Area- widespread control • Containment area- control in priority high value natural areas For occupiers holding responsibilities for control of infestations in the RPPMS 2001,	To control contorta pine within the Control Area by 2012 and prevent invasion to the Tararua and Ruahine Ranges Initial knockdown of contorta pine populations as directed	Horizons will undertake sustained direct control of contorta pine on private rateable land within the Control Area. This includes new seedling removal once landowners have fulfilled their requirements in

Council and year of RPMS	Conifer species	Status in plan/ plan rules	Plan objectives	Council actions
		contorta pine is to be under sustained control (3 year rotation) with goal of zero density NZDF & DOC chosen to manage contorta pine on land they administer & are responsible for maintaining sustained control (3 year rotation) Kariori Forest & roading authorities are responsible for sustained control of contorta pine (on 3 year rotation) on lands they administer Rules All occupiers to remove all seeding contorta pine within 5 yrs in designated areas Detailed rules specify contorta pine removals required by occupier of Kariori Forest Every roading authority to identify & destroy any contorta pine in road reserve within Contorta Pine Control Area at least once per year No person shall knowingly sell, distribute or propagate *Pinus contorta* subsp *contora* & subsp *marrayana*	under the RPPMS 2001 completed with exceptions for infestations addressed by specific rules Establish an interagency strategy for the management of contorta pine on the Volcanic Plateau Outcomes: Contorta pine to zero density in Control Area & controlled with other agencies Coherent strategic approach to contorta pine management across the Volcanic Plateau protects natural values High value natural areas are prioritised for protection under the Regional Biodiversity Programme are maintained free of contorta pine	RPPMS 2001 Horizons will not control Pinus contorta outside the control area except for sites of high natural value where all pest management issues will be addressed Horizons to maintain & enhance relationships via a MOU with key land management agencies on the Volcanic Plateau Horizons monitoring- during control, annually for 5yr, then biannual After August 2011 success of programme will be evaluated & changes made if necessary
Marlborough	*Pinus contorta*	Land occupiers must destroy all *Pinus contorta* spreading out from Contorta Containment Areas before they cone; except if the land is directly adjacent to the Wye Reserve Contorta Pine Containment Area Land occupiers must notify Council of new infestation of *Pinus contorta* within Wye Reserve Contorta Pine Containment Area	To prevent the spread of *Pinus contorta* from Contorta Containment Areas into other parts of South Marlborough	In partnership with DOC, implement a management programme to control the spread of *Pinus contorta* from Wye Reserve Contorta Pine Containment Area before coning In partnership with DOC, carry out inspections to monitor for presence of *Pinus contorta* on land surrounding containment areas Encourage landowners to control

Council and year of RPMS	**Conifer species**	**Status in plan/ plan rules**	**Plan objectives**	**Council actions**
				other wilding conifers species
Tasman/ Nelson	N/A			
Canterbury 2005-2015 with 2011 review	Wilding conifers	Land occupiers to take all steps “as reasonably necessary” to prevent the spread of self-seeded wilding conifers. Exemptions available [provision added 2011] Rely on National Pest Plant Accord to prohibit sale & distribution of *Pinus contorta*	Protect biodiversity in targeted areas by eradicating all self-seeded wilding conifers in targeted high value areas	Identify areas of high environmental value and prioritise wilding conifers programmes Facilitate or carry out control operations for outliers & fringe spread within targeted high value areas Facilitate community & land occupier self-help programmes for outlier wilding conifers in & adjoining areas of high environmental value subject to control Encourage land occupiers to remove high-risk shelterbelts and amenity plantings from areas in or adjacent to areas of high environmental value subject to control
Otago 2009	*Pinus contorta*	Occupiers must destroy all *Pinus contorta* except within *Pinus contorta* clearance and containment areas identified in Apendix 5 Occupiers within a *Pinus contorta* clearance area must progressively destroy *Pinus contorta* so that the area is clear by 2014. Then all *Pinus contorta* is to be destroyed before coning Occupiers in containment areas must ensure no coning age *Pinus contorta* is located where the seed could spread beyond boundaries	Total control of *Pinus contorta* outside of containment areas Total control *Pinus contorta* spread within containment areas Progressive control of all *Pinus contorta* within clearance areas	In monitoring pest plants Council will identify *Pinus contorta* and destroy if negligible cost Work with occupiers of *Pinus contorta c*learance areas to ensure trees on most exposed sites are removed first
Southland 2007	Contorta pine and	Contorta pine and mountain pine are containment plants for the whole region	To destroy contorta pine where it is found	Occupiers within the Mid Dome Wilding Trust Programme Area are

Council and year of RPMS	Conifer species	Status in plan/ plan rules	Plan objectives	Council actions
	mountain pine *(P. mugo)*	Land occupiers must destroy all contorta pine and mountain pine on land they occupy No sale, propagation or transport of contorta pine or mountain pine	To destroy mountain pine where it poses a serious risk To contribute to the programme to control contorta pine & mountain pine within the Mid Dome Wilding Tree Area To initiate a public awareness campaign on contorta pine and mountain pine To gather information on the distribution, density and abundance of contorta pine and mountain pine	expected to co-operate with any organised control programme. Control will be by Environment Southland unless occupiers agree to carry out the control themselves Public awareness campaign Monitoring

20.7 Appendix 7: District plan provisions relevant to wilding conifers: selection of South Island District Plans

Council & Date	Introduced conifer Species	Zone/area/overlay	Policies & Methods	Rules
Hurunui 2003 (Hurunui District Council 2003)	Not specified	Forestry Management Area Outstanding landscape areas		Rule A 1.3. Forestry is a restricted discretionary activity where Council has restricted its discretion to matters relating to the risk of wilding conifers spread and potential impacts Rule A 2.4.1. Forestry is a restricted discretionary activity where there is a major river valley, mountain range, main divide, coastal plains, coastal hills, soft rock downland, hard rock hills, Hamner Basin floor Rule A 2.4.2. In assessing applications Council has restricted its discretion to matters affecting landscape & visual matters including (indigenous vegetation) siting, plantation design and choice of species to minimise risk of wilding tree spread
Mackenzie 2004 (Mackenzie District Council 2004)	All contorta pine, Scots	Rural	Rural policy 3E To control the adverse effects of siting, design and potential wilding tree spread from tree planting throughout the District	Rule 6.2.1-2.Tree planting is a controlled activity outside the Mackenzie Basin in areas of tussock grassland/ indigenous scrub up to the least of 50ha or 10% title; or any size if not in tussock grassland. Council can address effects on landscape, ecological and wilding conifer spread matters Rule 6.2.3 Forestry >2ha/title/5yr within catchment of Downlands Water Supply or Timaru Water Support is a restricted discretionary activity. Council can address growth & spread of wilding conifers and effect on availability of ground & surface water Standards: No trees above 900m altitude; no planting contorta pine, Scots pine, dwarf mountain pine and

Council & Date	Introduced conifer Species	Zone/area/overlay	Policies & Methods	Rules
	pine, dwarf mountain pine and mountain pine All			mountain pine 6.2.5. Forestry in Mackenzie Basin (excl permitted, discretionary & non-complying); within 100m of a lake; within 20m of a river bank & within 50m of a wetland is restricted discretionary. Council can address impacts on ecological, landscape and ground & surface water Tree planting >900m altitude & in scenic viewing areas is a discretionary activity Tree planting in identified sites of ecological significance and in wetlands is a non-complying activity Rule 16.5 contains general resource consent assessment criteria (for use when Council has not restricted its discretion). (e)Criteria for tree planting applications. These include risk of wilding tree spread and impacts; impacts on high altitude ecosystems & landscapes; impacts on riparian and catchments including wilding tree management
Central Otago 2008 (Central Otago District Council 2008)	All Douglas fir, European larch, Ponderosa pine, Bishops pine, maritime pine, radiata pine Corsican pine	Rural Resource Areas	Policy 4.4.1. To manage the effects of land use activities... to ensure the adverse effects on open space, landscape, natural character, and amenity values are avoided, remedied or mitigated by: (e) location of tree planting especially in respect of landscape, natural features and ecological values (f) controlling the spread of wilding trees	Rule 4.7.4. (v) Tree planting not in the immediate vicinity of a building is a restricted discretionary activity (viii) Tree planting to establish a woodlot, production forest, shelterbelt >8m and consisting on Douglas fir, European larch, Ponderosa pine, Bishops pine, maritime pine, radiata pine is a discretionary activity When making its decision Council is to have particular regard to factors affecting the potential for wilding conifer spread and the associated impacts, and plans for managing spread (ix) Planting of Corsican pine is a discretionary activity.

Council & Date	Introduced conifer Species	Zone/area/overlay	Policies & Methods	Rules
	Scot's pine, mountain pine Contorta pine			Matters to be assessed are as for (viii) Rule 4.7.5 (v) Tree planting with Scot's pine and/or mountain pine is a non-complying activity Rule 4.7.5.A Planting contorta pine is a prohibited activity
Queenstown Lakes District 2009 (Queenstown Lakes District Council 2009)	All Contorta pine, Scot's pine, Douglas fir, European larch, Corsican pine, radiata pine All	Rural	Policies address landscape protection generally	Rule 5.3.5.1. (vii)No forestry or shelterbelt planting above 1070m altitude; (xii) No exotic tree or shrub planting or clearance of indigenous vegetation above 1070m altitude; (xiii) No planting of the following species with wilding potential- contorta pine, Scot's pine, Douglas fir, European larch, Corsican pine, radiata pine Rule 5.3.3.3 Forestry is a discretionary activity; tree planting is a restricted discretionary activity 5.4.2.2. Assessments in outstanding natural landscapes and visual amenity landscapes: existing vegetation planted after or self –seeded and <1m tall as at 28/9/02 and obstructs views from roads is not to be considered beneficial for assessment purposes, is not part of the permitted baseline and its removal shall not be considered a beneficial effect of a proposal Rule 5.4.2.3 Assessments general (xviii) forestry- matters Council is to take into account include potential to: cause wilding spread; adversely affect landscape values; adversely affect ecological values in the surrounding environment (xi) Tree planting – matters Council is to take into

Council & Date	Introduced conifer Species	Zone/area/overlay	Policies & Methods	Rules
		Open Space-landscape protection	General landscape protection policies	account include potential for wilding spread Rule 20.2.2.5. Forestry activities are non-complying activity except for the removal of wilding tree species Rule 20.2.2.6. Planting of any wilding tree species is a prohibited activity
Clutha 1998 (Clutha District Council 1998)	Not specified	Rural Resource Area	Methods RRA5 Wilding Tree Spread (encourages prospective tree planters to consider wilding tree spread)	
Southland 2001 (Southland District Council 2001)	Scots pine, Corsican pine, Douglas fir, all larches Contorta pine, mountain pine (also grey & crack willow & sycamore)	Mountains Resource Area Mountains Resource Area	Policy MRA.3 To mitigate or avoid the adverse effects of Wilding Trees in the Mountains Resource Area while recognising the need for the repair and/or maintenance of existing soil conservation and river protection works undertaken pursuant to Rule MRA.3a	Rule MRA.2 Planting of these species is a restricted discretionary activity. Council shall restrict its discretion to : Wildling Trees Risk Assessment; Wilding Trees Management Plans, location, plantation configuration and species selection to avoid Wilding Tree spread; Setback from adjoining properties; protection of riparian & wetland areas; location of access roads, tracks & earthworks Rule MRA.3 Except as provided for by rule MRA3a (crack willow) planting of these species is prohibited

20.8 Appendix 8: Summary of Central Government wilding conifer management activities and funding

(Sources: Interviews with agency staff, completed questionnaires and various reports and papers)

Agency	Summary of activities	Funding	Monitoring extent	Notes
Department of Conservation, Hawke's Bay-Wellington Conservancy	Contorta pine management since 1985 Based on strategic plan which is regularly updated (Department of Conservation 2010) Total control, four-year rotation for follow-up control, monitoring spread, do-nothing areas Wide range of tools used including hand-tools (volunteers), chainsaws (DOC & contractors), heli-skid, human sling & aerial spray	2009/2020 $102,00 2010/2011 $85,000	yes	14,000ha wilding contorta pine in Kawekas & eastern Ruahines. Density range: scattered trees to 10,000/ha. Trees to 45yrs age
Department of Conservation Tongariro Taupo	Control is on 3yr rotation Most helicopter flown, with workers set down to cut/pull trees Small areas ground based control (easy access) Limited helicopter strop work in inaccessible locations	Relative funding is declining as inflation is leading a reduction in the area controlled	Yes since 2001	Control wilding conifers on 132,236ha
Department of Conservation Nelson-Marlborough	DOC only controls wilding conifers on a small percentage of land they administer (mainly radiata & contorta pine, & Douglas fir) Seek a 3yr return time Aerial application of grazon & diesel is revolutionising ability to control wilding conifers	$208,000/yr		Control wilding conifers on 119, 010ha
Department of Conservation Canterbury	Wilding conifers control has been undertaken for about 25 yrs, but has increased in last 15yr Main species controlled are contorta pine, mountain pine, Douglas fir. There are also experimental plantings and removal of radiata pine on Banks	$600,000/yr although double this could easily be spent This includes additional funding for controlling wilding conifers on lands coming into DOC	yes	400,000ha are under management with density ranging from dense stands of wilding conifers to widely scattered outliers

Agency	Summary of activities	Funding	Monitoring extent	Notes
	Peninsula Variety of methods are used Control strategies range from consolidating areas already started, to follow-up, to controlling new invasions Work ranges from controlling source plantings to scattered outliers DOC organises control for regional council, LINZ, land managers & community groups	management as part of the tenure review process (although this funding does not cover all costs)		Much of the work is in tussock, scrub and grasslands
Department of Conservation, Otago	Wilding conifer management for 20+yr Site-led projects for protected areas , usually several introduced conifer species & often other pest species Targeted wilding conifer management in seven large conservation areas Wide range methods used	The 7 areas where there is targeted wilding conifer management are funded from the South Island Wilding Pine Fund: 2009/2010 $220,000 2010/2011 $203,000 Funding for site-led projects unknown	yes	Inventory of wilding conifers shows many protected areas are affected by wilding conifers
Department of Conservation Southland	25+ years Management Strategy- eradicate or very low densities Cutting, drill & poison, mulching (expensive) Trials aerial basal bark and aerial boom spraying inconclusive	Blue Mts 2009/10 $39,000 2010/11 $42,000 Eyre Mts 2009/10 $20, 270 2010/11 $40,000 Takitimu Mountains 2009/10 $75,000 2010/11 $83,000 Mid Dome 2009/10 $465, 467 2010/11 $425, 000	Formal for Takitimus and Mid Dome Others Informally	Budget cuts for 2011/12

Agency	Summary of activities	Funding	Monitoring extent	Notes
Ministry of Defence Department Waiouru	40 years of management Management regime has changed over time as the nature of the problem has changed Currently much control is helicopter based and they choose methods including ground cutting, boom spraying and spot spraying Annual abseiling team does control work on bluffs An unexploded ordinance zone is blanket-sprayed every 5yrs and spot sprayed annually	$900,000/yr for contorta pine control	yes Annual using data from operators	63,000ha Density has significantly decreased over time End of year reports and data from operators used to plan work programme for the following year
LINZ	Wilding conifer management for approximately 10 yrs Cut down trees >1m height; remove rest using hand methods, spray or scrub-bar	Woody weed control on high country land $700,000 in 2007/08		Weed control planning & management by contract

20.9 Appendix 9: Summary of regional council wilding conifer management activities and funding

(Sources: Interviews with council staff, completed questionnaires and various reports and papers)

Agency	Summary of activities	Funding	Monitoring extent	Notes
Northland	Removing a variety of pine species from Whangarei Heads using aerial spraying, drilling and killing and hand cutting. Control pines as part of a community plan			
Waikato	Has been supporting contorta pine control in the "alpine" areas south of Turangi since 1997. Main areas of work are non-Department of Conservation land in Kaimanawa Ranges, land adjacent to the Desert Road and Tongariro National Park. Works closely with other agencies. Approaches have included aerial surveys, helicopter skid hopping and sling loading, ground control. Densities now at very low levels with on-going surveillance In East Taupo working with landowners to control contorta pine	$10,000/year for "alpine" area south of Turangi		
Horizons	The RPMS defines a control area (Volcanic Plateau) where council undertakes active control of contorta pine on private land; Karioi Forest and other agencies control contorta pine on own lands Goal is zero density by 2012 Control followed up every 1-3yrs until zero density; also downwind surveillance Containment area for contorta pine is outside control area – here control occurs if there is a threat	Increased to $125,000/yr	Yes	Contorta pine widely planted for shelter & firewood on farms, in Karioi Forest and by the Crown on Ruapehu

Agency	Summary of activities	Funding	Monitoring extent	Notes
	to site biodiversity values			
Marlborough District	Contorta pine is a containment pest in RPMS South Marlborough- contorta pine control work using skid-hop and cut methods Northern Marlborough –radiata pine on lands of different tenures Management by community trust that includes council and Department of Conservation (ex officio) – Primary method of control is stem injection of poison	$40,000 for contorta pine control $20,000 to community trust	Some None by council, some by Trust	South Marlborough contains relatively large areas of Crown legacy plantings of problem conifers and includes Molesworth Station North Marlborough contains extensive areas radiata pine spread from plantations & homesteads. Marlborough Sounds Restoration Trust established
Canterbury Regional Council	1992-collection of data, facilitating volunteer & landowner clearing activities 2003- funding for priority areas 2011- introduction requirement for landowners to clear where it is reasonable for them to do so	2010/2011 $260,000 operations $40,000 monitoring & surveys	Yes on a ten year rotation for the High country	
Otago Regional Council	ORC worked with forestry companies and now all production stands of contorta pine have been removed Since 2001 there has been a requirement (in RPMS) for landowners to remove contorta pine at their expense ORC does not do any control	No funding	4 yearly inspection of some areas (excludes DOC land & area managed by WWCCG)	Most land with contorta pine is administered by DOC and/or within the area covered by the Wakatipu Wilding Conifer Control Group (WWCCG)
Environment Southland	Contorta pine and mountain pine containment pests in RPMS Active role funding & supporting Mid Dome Wilding Tree Trust. Advisory since 1999. Began funding	Mid Dome contribution 2006 $300,000 Thereafter $50,000/yr Mid Dome currently receiving half	Not formally	Mid Dome Trust $400,000/yr for 12 year programme

Agency	Summary of activities	Funding	Monitoring extent	Notes
	contribution in 2006	funding needed to cost-effectively meet goals (seeking further $4 million to complete by 2018/19)		

20.10 Appendix 10: Current research related to wilding conifer management in New Zealand

20.10.1 Research that is *directly* related

Title	Brief description	Agency	Major players	Location	Currently funded by
Modeling wilding risk and spread	Spatial mapping of wilding risk assessment DSS	Scion	Thomas Paul, Nick Ledgard	South Island	NZWCMG?
	Probability models for conifer seed spread and establishment	Scion	Thomas Paul	South Island sites	NZWCMG?
Douglas fir invasion of beech	Comparative growth rates relative to canopy light	Scion	Thomas Paul, Nick Ledgard,	Queenstown and Burnt Face (Craigieburn Range)	NZWCMG?? DoC.
Shade tolerance of exotic conifer seedlings under native shrubs	Survival and growth of exotic conifer seedlings under Kanuka/manuka and in the open	Scion	Murray Davis et al 2011	South Island	DoC, Scion Capability fund
Native regeneration under conifers	Natural regeneration of native plants under dead conifers, and determination of C loss from conifers relative to C storage within natives	Scion	Thomas Paul, Nick Ledgard	Marlborough Sounds	Scion Capability Fund
Establishing native forest species under conifers	Using conifer 'nurse' cover to establish native	Scion	Thomas Paul, Graham Coker, David Henley	Tekapo (Balmoral	Scion Capability Fund

Title	Brief description	Agency	Major players	Location	Currently funded by
	forest species by planting and seeding		and Nick Ledgard	station), Mid Dome	
Establishing native forest species under conifers	Using conifer 'nurse' cover to establish native forest species by planting and seeding	DOC	Clayson Howell	South Marlborough	DOC
Control wildings for restoring native vegetation – the role of control area size	Size of control areas relative to restoration requirements	DoC	Clayson Howell, Kate McAlpine	Kawekas and Marlborough Sounds?	DoC
Herbicides for wilding control (this is the latest series of trials and brings together disparate past trials)	Determining most cost-effective 'brews' for killing wildings – ground application (mainly basal bark) and boom/lance application from the air	Department of Conservation Scion ECan	Lynne Huggins & David Miller (DOC) Pete Raal and Pedro Willemse (DOC), Stefan Gous (Scion), Andy McCord (Forestry Services Ltd) and David Hewson (ECan), Mike Watt	Mid Dome Queenstown, L. Pukaki, Craigieburn areas	Various
Other operational control 'trials'	Many control operators are trying variations of core techniques to suit different circumstances	Wilding control contractors	A number – people like Wayne Godfrey and Marty Grounds	All over the country	Various
Impact of conifers on soil organisms and vegetation successions	Looks at soil microflora / fauna under wildings at different densities, and associated vegetation changes	Landcare Research	Duane Peltzer, Ian Dickie, Larry Burrows, David Wardle	Mt Barker (L. Coleridge), Craigieburn Forest Park, Kaweka Forest Park.	MSI
Weed impacts on ecosystems -comparing	Removal experiments to determine weed species'	Landcare research	Duane Peltzer, Ian Dickie, Larry Burrows,	Mt Barker (L. Coleridge),	MSI

Title	Brief description	Agency	Major players	Location	Currently funded by
presence and removal of conifer species	impacts above- and belowground. Uses 20 x 20 m plots; weeds removed on half of the plots. Plan to remeasure in 2013- 2015		David Wardle	Craigieburn Forest Park, Kaweka Forest Park.	
Plant-soil feedbacks following pine removal	Pot experiments to look at legacy effects in soils and their effects on native and non-native plants following removal of *Pinus contorta*	Landcare Research	Ian Dickie Duane Peltzer	Craigieburn Forest Park	MSI
Plant –soil interactions in home versus introduced ranges for *Pinus contorta*	Investigation of why species are invasive in some countries, but not others	Collaborators + Landcare Research	Michael Gundale, David Wardle (Sweden), Duane Peltzer, Ian Dickie	Various	MSI/Swedish proposal submitted
Variability in invasion by *Pinus contorta*	Investigation of controls on *Pinus contorta* invasive success among countries	Collaborators + Landcare Research	Bruce Maxwell (US), Martin Nunez (Argentina), Anibal Pauchard (Chile), Duane Peltzer, Ian Dickie	Various	NSF/MSI
Models of Pinus nigra demography and seed dispersal	Modelling spatial spread including long-distance dispersal	CSIRO/ University of Queensland	Yvonne Buckley, Paul Caplat, Ran Nathan	Mt Barker, L. Coleridge	ARC (Australian Research Council)
Spatial models of Pinus nigra dispersal and management	Applying dispersal model and field experiment data to test the effectiveness of various management scenarios	Landcare Research/CSIRO	Yvonne Buckley, Paul Caplat, Duane Peltzer, Ian Dickie	Mt Barker, L. Coleridge	ARC (Australian Research Council)
Plant, animal, fungal	Field evidence for	Landcare	Ian Dickie, Janet	Various	Landcare

Title	Brief description	Agency	Major players	Location	Currently funded by
disperal mutualisms	invasional meltdown involving wilding conifers, mycorrhizal fungi, and mammal dispersers.	Research	Wilmshurst, Jamie Wood		Research Capability Fund

20.10.2 Research that is *indirectly* related

Title	Brief description	Agency	Major players	Location	Currently funded by
Performance of exotic tree species on eroded sites	Productivity of exotic conifers on depleted and eroded farm sites	Scion	Dave Palmer *et al*	Catchment in the North Island	MSI/FFR
Global distribution modelling of weed species	Climatic envelope modelling of major weed species and the changes in distribution driven by climate change	Scion	Kriticos (CSIRO), Watt (Scion)	globally	
New Zealand drylands- native woody vegetation succession processes and pathways	Determining natural patterns and ecological succession pathways for drylands – includes development of conceptual models	Landcare Research	Susan Walker, Adrian Monks, Larry Burrows	South Island drylands (east coast interior)	MSI

Information in both tables is provided by Nick Ledgard; Thomas Paul, Graham Coker of Scion; and Duane Peltzer, Ian Dickie, Larry Burrows of Landcare Research
As at July 2011

20.11 Appendix 11: Case studies

20.11.1 Purpose of the case studies

The purpose of this section of work is to identify lessons to be learned from a group of case studies addressing different approaches and contexts for wilding conifer management. In addition to these case studies, examples that illustrate issues of concern and/or good practice are referred to in the text of the main report.

20.11.2 Wilding control using more cost-effective techniques on lands of different tenure in the Mackenzie Basin

As part of the Department of Conservation's research on more cost-effective wilding control methods, staff decided to work with local contracting companies on new control techniques. Initially the focus was on using scrub bars. Other new methods included:

- Basal bark application (ground based) using an oil carrier and systemic herbicide to chemically "ringbark" the target tree (for sparse infestations)
- Aerial basal bark application with an oil carrier and systemic herbicide to chemically "ringbark" the target tree using a 2.5 m hand held wand from the door of the helicopter (for sparse infestations)
- Aerial boom spraying using a water carrier with systemic herbicide and additives (for dense stands / closed canopies of trees)

Once the new methods were proven useful, adjoining land managers were given the chance to make use of the contract teams whilst they were working in the Mackenzie basin. After some of the landowners successfully used the contractors and the new methods, word spread and others then participated.

This has been beneficial for all involved. The Department of Conservation ensured that seed source trees were removed, so areas that had been cleared were not reinvaded. The contractors had additional work and responded by devising new, more effective ways of working. Landowners had cost effective work carried out without having to pay travel time to get the crews in place. The new methods reduced control costs for everyone, enabling more wilding infestations to be controlled.

A Canterbury wide working group involving the Department of Conservation, LINZ and Environment Canterbury determined that the Department of Conservation was best placed to lead wilding conifer control work in the Mackenzie. In accordance with this the Department of Conservation has been project managing Environment Canterbury funded wilding control work to ensure that the Council's programmes (focusing on control in areas with high biodiversity value) are coordinated to provide best value for money. Land Information New Zealand (LINZ) has a national pest control programme and the associated wilding tree control for the Mackenzie is being coordinated with Department of Conservation work.

As a result of the increased dialogue with locals and other organisations there have been additional initiatives, such as wilding tree control events for volunteers and workshops to demonstrate new techniques. The initiatives have also led to more coordination of a much wider range of pest issues, from wildings to rabbits. Agencies involved in this co-ordination include Department of Conservation, Environment Canterbury, LINZ, local councils and Meridian.

The total area (on lands of all tenures) subject to wilding conifer control is not known at this stage. The Department of Conservation estimates that wilding conifers on public conservation land are 95% controlled. There is only one large stand of original plantings left on public conservation land and that particular area is programmed for removal this summer. Once this stand is removed wilding conifer control for all current public conservation land in the Mackenzie will be in maintenance mode.

(Information provided by Helen Braithewaite and Peter Willemse of the Department of Conservation, Ray Maw of Environment Canterbury)

Lessons learnt:

4. Effective co-ordination between public agencies can achieve more than agencies acting alone
5. Working with local contractors helped the Department of Conservation with developing and refining control methods, and with making them available to others. This helped facilitate effective control on neighbouring properties, thereby reducing long-term risks for the Department of Conservation managed lands
6. Sufficient resources and the refinement and application of innovative methods on Department of Conservation managed land means that by the end of the 2011-2012 summer wilding conifers will be controlled on all current public conservation land in the Mackenzie Basin. Ongoing maintenance control will be required to remove trees that were missed and seedlings germinating from the soil seed bank as well as seed that has blown in from other properties.

20.11.3 An example of sustained control of contorta pine over many years by the Ministry of Defence

The Waiouru Military Training Area (WMTA) comprises approximately 63,000ha of New Zealand Defence Land on the North Island Volcanic Plateau. This area contains undulating and plateau topography, with deeply incised river valleys and widespread swamps and bogs in poorly drained areas below the treeline. Over two thirds of the area is over 1000 metres above sea level. In 2001 the montane-subalpine vegetation on the land was described as comprising extensive areas of red tussock (*Chionochloa rubra*) grassland, mixed shrublands and patches of mountain beech (*Nothofagus solandri var cliffortioides*) (Burns et al. 2001). Manuaka and monoao (*Dracophyllum subulatum*) were re-colonising tussock grasslands on many hill-slopes.

The red tussock grasslands are thought to be human-induced, resulting from two large fires that cleared the original forests about 500 years ago (Fromont 2008). Repeated burning and stock grazing meant that the tussock grasslands remained. However, recent land use changes (including

fire and grazing suppression) have led to natural succession changes from tussock grassland to heather and native scrublands, and eventually native forest for areas below the treeline (Fromont 2008).

(Burns et al. 2001) reported contorta pine at varying densities over almost all of the area, apart from small areas of beech forest. The main source of contorta pine seed was Karioi Forest (bordering the WMTA to the west), primarily plantings made between 1928 and 1933 by the former New Zealand Forest Service (Wardrop 1964) (cited in Burns et al. 2001). Concern was first expressed about the spread in 1959 and by 1964 contorta pine was present at varying densities over 13,355ha (Wardrop 1964) (cited in Burns et al. 2001). By 1975 at least 20,000ha contained dense to scattered infestations, with infrequent occurrences elsewhere (Hogg & Garrett 1975).

Control of contorta pine began in 1972. Initially, dense stands were roller crushed or chain sawed and then burnt. In low density areas hand cutting and rotary slashing methods were used. Considerable trial work was undertaken to identify an appropriate chemical to control a dense infestation ("Zone 20"), covering 1500ha near Lake Moawhango (Burns et al. 2001). Zone 20 contains unexploded ammunition and foot and vehicle access is prohibited.

From the mid 1980's to 2001 contorta pine was controlled in the open grassland areas with ground-based cutting (using scrub-bars) or pulling by contractors, within defined 1500ha management blocks that were revisited every four years. In tall scrub and higher altitude areas with lower densities of contorta pine, helicopters were used to move crew. Industrial abseilers were used to progressively remove contorta pine from steep gorge systems. In the early 1990's much of Zone 20 was sprayed and burnt, although 20% remained uncontrolled providing an on-going seed source. This area was sprayed subsequently biannually. In 1995 a logging contract removed all the mature trees around the Waiouru Camp making use of a short-term market opportunity. Throughout this time the WMTA was under adequate control, with substantial progress being made in reducing the highest density infestations. However, by 2001 there had been little recent reduction in contorta pine densities in areas subject to the four-year cutting cycle. Some areas still had 4000 stems per hectare after years of high quality control on a four year cycle.

In 2001 John Mangos, northern land manager for the New Zealand Defence Force commissioned Landcare Research to review the contorta pine control programme with the objectives of: determining strategies that would reduce the rate of contorta pine re-establishment following control; and suggesting strategies that would improve contorta pine management. The Landcare Research review (Burns et al. 2001) found that:

- Many individual trees were surviving the four yearly control operations. In tussock grassland and short subalpine vegetation a residual population of mostly 1-2 year old trees were not detected and removed, probably because they were generally shorter than the surrounding tussocks and shrubs and inconspicuous. In taller scrub detection was more difficult and some trees were escaping detection and control on more than one occasion
- While ineffective cutting (not cutting below lowermost branch) was rare, it was still a source of residual trees
- At altitudes below 1000m some 4-year-old trees had mature cones, although most did not produce mature cones until age 5. With a 4-year rotation inconspicuous 1 or 2 year-old

trees that survive a control operation would be 5 or 6 before they are targeted again. This meant that they were probably producing seed before removal. Trees in scrub areas were not controlled until they were older than 10 years, by which time they were producing abundant seed

- The discovery of abundant coning trees at low altitudes and young trees around the remains of cut trees suggested that seed for re-establishment was mostly coming from previous trees on the site rather than long-distance dispersal. Long-distance dispersal was still a source of occasional recruits , especially from high-risk take-off sites
- No pines were seen in the gorges treated so far suggesting that abseiling had been effective
- Most contorta pine in Zone 20 were standing dead trees and there was no evidence of regeneration beneath these trees

These and other findings led to the following recommendations (Burns et al. 2001):

- Improve location and removal of small contorta pine individuals during ground control operations
- Cut all trees below the lowermost branch to prevent re-growth
- Reduce the control rotation for contorta pine in short-stature vegetation to once every 3 years
- Aerially search for and remove contorta pine from scrub annually
- Complete control operations before late summer/autumn when seed is due for release
- Prioritise the removal of contorta pine from steep areas that act as seed take-off sites
- Continue herbicide application in Zone 20 (but reducing the area treated and frequency of application if possible)
- Adopt an adaptive management regime based on further population research

The Defence Force responded to the recommendations by changing the cutting cycles from 4 years to 3 years over a two-year period and finishing the work by the end of February. These two changes led to an almost immediate reduction in density in the high-medium density areas. This meant that size of control blocks could be increased to 5000ha and helicopters could be used.

In early 2008 the Defence Department commissioned a review (Fromont 2008) of ecological succession processes in the WMTA and the implications of this for military training and environmental management. A comparison between a 2004 helicopter survey of scrub extent (Kingett Mitchell 2004) and the 1997 topographical maps showed that had been a significant expansion of manuka scrub on steep slopes between major bush areas. This and other observed natural succession changes are proceeding at faster rates than those seen in the drier and colder eastern South Island tussock grasslands that had had a forest cover prior to human arrival. Fromont (2008) predicted the following noticeable changes would occur within the WMTA within the next 20-50 years:

- Tussock above 1000m altitude would be replaced by dracophyllum and subalpine shrubs and the introduced heather would become more common in high altitude areas
- Dense manuka scrub would cover most of the hill crests and slopes in mid and low altitude areas and spread extensively across flat areas, including Zone 20
- Heather and dracophyllum would continue to increase in the Rangipo Depression and spread across low-altitude areas east of the Desert Road

- Heather and manuka would spread extensively across the southern sector

Tussock vegetation was expected to retreat to natural non-forest areas (e.g. alpine sites, cold air inversion basins and wetlands). Manuka was expected to be an effective control tool for heather, gorse, broom and lupin in many areas. It was thought that these weeds might persist in cold hostile environments (e.g. Rangipo) which were expected to remain open for longer. Although a light-demanding species, contorta pine can establish and grow through dense manuka scrub. Because of this Fromont (2008) considered that the control of contorta pine would become more difficult because the trees would become harder to locate and access. Following this report the New Zealand Defence Force has chosen the minimal management option. This means that natural succession processes will prevail over most of the WMTA, with the firing ranges and training utilities retained and the road and track network upgraded.

By late 2008 the Defence Force had moved from contorta pine ground control teams to annual helicopter operations. The helicopter contractor decides which specific control methods (ground cutting, boom spray, spot spray) to use in particular situations/locations. The contorta pine control blocks have increased to 9000ha and the helicopter contractor uses GPS with data downloaded each night to a central database. In addition, abseilers remove pines from specified deep gorges and Zone 20 is aerially sprayed.

Monthly/ end -of -season contractor reports are used as the basis for planning the next month's/ next season's activities. These reports provide GPS data and maps. There are good health and safety protocols and there have been no aerial or ground accidents. Payment is for each hectare controlled. As aerially based control is now carried out by a company with a team of people and a number of helicopters and fixed- wing planes, equipment can be upgraded to make use of new technology. With natural succession processes leading to an expansion in the area of scrub, contorta pine control for most of the WMTA is now annual. The costs for controlling the entire area (60,000ha/yr) are the same as when there was a four year control cycle (15,000ha/yr). In addition to reports by consultants it is likely that the Ministry of Defence has also benefited from being actively involved with the long-standing central North Island *Pinus contorta* co-ordinating committee (Section 9.4).

Information sources: Minutes of the *Pinus contorta* co-ordinating meeting held in Waiouru on 25 September 2008, John Mangos of the New Zealand Defence Force, references in the text.

Lessons learnt

- Good science and technology improvements lead to more effective wilding conifer management and monitoring over larger areas
- In comparison with most other wilding conifer control programmes this programme has been very well resourced over the years. This has facilitated the use of adaptive management to revise and refine cortorta pine control methods in some very challenging situations (e.g. steep gorges, zones with un-exploded ordinance)
- Contorta pine will persist on sites where there is a local or neighbouring ongoing source of seed, even if there are contorta pine control operations
- The length of the control cycle used in wilding conifer control programmes needs to be selected with great care. In the central North Island a contorta pine control cycle of four

years meant that 1-2 year-old trees were often not detected in tussock grasslands and so they had time to produce viable seed before the next control cycle. This allowed medium-high densities of contorta pine to persist in spite of ongoing control. Reducing the control cycle in open areas to 3 years led to significant reductions in contorta pine densities
- Contorta pine is harder to detect and access in scrub and so is more likely to produce viable seed before it is removed. Annual aerial control was recommended for scrub areas to improve the chances of detection and removal at the earliest possibly time
- Natural succession processes in areas of human-induced grasslands will change the impacts of, and control requirements for, different weed species, including wilding conifers. These succession processes are more rapid in the North Island

20.11.4 Horizons Regional Council comprehensive RPMS methods for the control and containment of contorta pine

The previous operative Regional Pest Management Strategy (RPMS) for Horizons Regional Council required most landowners to control all seeding contorta pine on their properties by August 2006. Following the expiry of the August 2006 deadline Horizons issued a *Notice of Direction* to all landowners who had not complied and began actively negotiating with landowners to control contorta.

The current operative RPMS came into effect in May 2007. Horizons continued to work with landowners who had not fully complied with their obligations under the previous strategy. Once the landowners had complied, Horizons took over responsibility for follow-up work. Under the current strategy there is a *control area* centred on the Volcanic Plateau as this is where contorta pine is having the most significant adverse effects on natural ecosystems. Here the target is zero density for contorta pine by 2012. The regional council undertakes active management of contorta pine on private and Maori land. Under the strategy the following agencies are responsible for controlling contorta pine where it occurs on land they manage within the control area: Department of Conservation, New Zealand Defence Force, Earnslaw One Forests (Karioi), TranzRail, and roading authorities. The agencies are required to maintain sustained control on a three year rotation.

New areas of contorta pine shelterbelts are still being found. This can sometimes be because the species in a shelterbelt has been incorrectly identified in the past. A recent aerial survey found potential areas that were subsequently confirmed as contorta pine shelterbelts with trees over 20m in height.

The active management of contorta pine by Horizons since 2007 (associated with revised provisions in the 2007 RPMS) was needed because the previous approach had only been of moderate success. For landowners the cost of control had been high, especially when the landowners considered that the plant could be a resource. Contorta pine had been widely planted for shelter and firewood. While it could be easily managed on farms the seed could spread considerable distances. It was also seen as a potential source of carbon credits under the ETS. Accordingly landowner control had focused on the easy-to-control contorta pine and there had not been the will to remove all plants.

The new provisions in the 2007 RPMS gave Horizons additional powers to ensure the removal of contorta pine from Karioi Forest. The contorta pine had originally been planted by the former New Zealand Forest Service beginning in 1928, although the trees had been managed by the private sector for some years. Contorta pine was also present in high altitude research trials established by the New Zealand Forest Research Institute. While Karioi forest and the trials have been major sources of contorta pine seed for other lands (e.g. New Zealand Defence Force land at Waiouru), there is now good control of these areas.

Horizons have also worked on removing contorta pine from other areas that posed risks to Tongariro National Park, the Kaimanawa Ranges and other natural areas. Outside of the Volcanic Plateau *contorta pine control area* is the *contorta pine containment area*. Within the containment area contorta pine control is only required in areas of high priority for biodiversity protection purposes.

By 2008 most landowners had complied with the previous strategy and Horizons had been progressively taking over areas that had initial knockdown treatment. At that time Horizons was "managing" approximately 30, 500ha of private land for contorta pine. Some areas had been controlled more than once with one area having been treated three times and going onto a three yearly maintenance rotation. Recently Horizons increased its annual allocation for contorta pine control and surveillance to $125,000/year. There are, however, still some blocks (mainly shelterbelts) of unrecognised contorta pine on a number of farms in the district (Nick Ledgard, pers. comm.). These blocks do need to be identified and landowners informed so that removal of these blocks can take place.

Information provided by Craig Davey of Horizons Regional Council; Horizons Regional pest Management Strategy, Minutes of biannual meetings of the *Pinus contorta* Co-ordinating Group (25 September 2008, 12 October 2010) and Nick Ledgard (formerly Scion)

Lessons learnt:

3. Invasive pine species such as contorta pine are not necessarily recognised as such by landowners. Landowners/occupiers do need to be made aware that they have invasive species such as contorta pine
4. Where RPMS rules for a particular species require landowners/land occupiers to control a species that some of those landowners/land managers perceive may have some economic value, compliance may be patchy and the outcome less than expected
5. A comprehensive approach, including appropriate rules, active negotiation with agencies and landowners/ land managers, and direct control work by the council was needed to achieve comprehensive control of contorta pine in an area with a zero density target

20.11.5 Mid Dome, an example of combined agency and community action in spite of escalating costs

The earliest record of Mid Dome in 1857 (by Thompson, Chief Surveyor for Otago to the Waste Land Board) described the summit area (above 2000-2500 feet) as having "hardy vegetation" with snow grass, lichens and heath, and being unsuitable for grazing. Forest on mid and lower slopes was burnt

from the 1850s and the resulting tussock grassland in this area (as well as that on the upper slopes) was repeatedly burned and heavily grazed by sheep and rabbits until the mid 20th century.

In the 1940s Mid Dome was described as one of the worse examples of erosion in Southland, where deposition of the eroded material was considered to pose a risk to the main highway and rail line (McSaveney & Davies 2001). Mid Dome was proposed as a showcase to demonstrate the virtues of soil conservation and in 1947 was voluntarily transferred to the Soil Conservation and Rivers Control Council for experimental purposes. The purpose of the initial experimental area of 425ha was to establish vegetation to control run-off so further gullying could be prevented. This area was extended to 657ha and gazetted under the Land Act 1948 as a Reserve for soil conservation purposes. There were many experimental trials, with 250ha planted with pines (primarily contorta pine and dwarf mountain pine (*Pinus mugo*)) in the early 1950s to the early 1980s. Contorta pine continued to be planted in spite of concerns being expressed about its risk of spreading in the early 1960s. To the south of the Soil Conservation Reserve is a 420ha block that the Southland Catchment Board began planting in 1963, making the total area of the Mid Dome/Cupola soil conservation reserve 1080ha.

50ha of the original 167ha of plantings of contorta pine and dwarf mountain pine in Tank Creek were cut in 1978. Unfortunately not all the green foliage was removed from many trees and they resprouted. Small numbers of trees were removed from adjoining farmland around 1990, and the Department of Conservation removed some trees after that. These actions were generally disjointed and did not provide the co-ordinated effort needed to make significant progress.

In 1976 the soil conservation reserve was transferred to the Minister of Forests to be administered as State Forest. The reserve status was revoked in 1995 and the area became Crown land administered by the Ministry for the Environment. In response to a 1998 government proposal to sell the Crown land with the densest infestations of introduced conifers, Federated Farmers called a meeting of landowners and other affected parties (including Environment Southland). The matter of greatest concern was that if the land was sold the liability for wilding tree control would pass to a new owner who would not be able to deal with the introduced conifer problems. In response to these concerns a Mid Dome Wilding Tree Management Group (MDWTMG) was formed to investigate the wilding tree problem at Mid Dome and look for solutions. The group consisted of representatives of affected landowners, Environment Southland, Department of Conservation, Ministry for the Environment, Southland District, Royal Forest and Bird Protection Society and others. Following action from the Group and the local Member of Parliament the land was withdrawn from sale.

In 1999 the Group commissioned a report (Ledgard 1999) to define the extent and nature of the wilding conifers problem at Mid Dome. Ledgard calculated that 13,653ha were affected by introduced conifers, including 270ha of dense infestation (>2000 stems/ha). This excluded a large area with scattered outliers to the east of the Mataura River. Most of the spread was from contorta pine, and some outliers were 40km away. While the dwarf mountain pine had not spread much, only 10% was coning regularly. Ledgard thought that it was likely that mountain pine would substantially increase soon, as had occurred in places like Mount Bee. Ledgard (1999) recommended the complete removal of all planted and wilding trees at a total cost of $900,000

including follow-up control and rehabilitation. He observed that while the spread of contorta pine had been less than what might have been expected (especially compared to Pukaki or the central North Island), had outliers been removed sooner the problem would have been much less.

The Ministry for the Environment commissioned in 2001 a scientific assessment) of the potential stability of the area if the wilding trees were to be removed (McSaveney & Davies 2001), which found that the erosion forms present and their scale were typical of those found elsewhere in the South Island high country. While depletion of plant cover had led to local soil loss, this had not contributed significantly to the large erosion events that caused the historical massive aggradation of the alluvial fans below Mid Dome and Cupola. These large scale erosion events resulted from the inherent erodibility of the very highly fractured local bedrock (in a tectonically active area) and rare very intense rainstorms. McSaveney and Davies (2001) concluded that erosion of this fault-shattered rock in intense storms is not moderated by vegetation. Large erosion scars are to be expected and the streams flowing from the area should from time to time carry and deposit large amounts of sediment. In contrast on the lower slopes of Mid Dome grazing still occurs and traditional soil conservation tools have been effective in limiting soil loss. This has not influenced the quantities of detritus being moved by Tank and Fiery Creeks.

McSaveney and Davies (2001) did not consider that the trees planted for “soil conservation” purposes to have had any useful influence on erosion or sedimentation and they expected their removal would also have no influence. One matter of concern was that of deteriorating slope stability over time as roots decay. While the very stony soils found in the upper area are not susceptible to shallow soil slips (type of erosion most effectively mitigated by roots), they noted that the trees had substantially dilated soil volume to greater depths than ever occurred under alpine vegetation (larger roots penetrating greater depths). The consequences of this were not specified (apart from increased soil permeability).

In 2002 the MDWTMG commissioned a study to model the long-term spread risks. This study indicated that if not controlled, dense wildings (>2000 stems/ha) would dominate 61,000ha of high country tussock and pastoral lease land with less dense infestations covering a much greater area by 2053. The Group also increased public awareness through volunteer work days.

The Mid Dome Wildling Tree Trust was formed as a charitable trust in 2006. Its primary goal is to remove planted stands and eradicate wilding conifers from Mid Dome and surrounding lands to the point that any regrowth can be managed by landowners. The Trust works collaboratively with the local community, landowners, volunteers, Department of Conservation, Environment Southland, Ministry for the Environment and LINZ to co-ordinate efforts to remove wilding conifers. This includes the preparation of a structured eradication plan, seeking funding, raising public awareness and continuing volunteer days.

The 12 year wilding tree eradication programme (Mid Dome Wildling Trees Charitable Trust 2008) outlines a programme of treatment for 70,000ha covering lands of all tenures. The Trust contracts Department of Conservation to provide advice and implement the programme. The Programme sets out milestones for each of four phases along with estimated budgets for each year. The twelve year

programme was costed at $8,560,000 which is nearly ten times higher than that estimated by Ledgard (1999) ten years earlier.

The Department of Conservation 2009/2010 operational report on the 12 year wilding tree eradication programme reported that $487, 300 was spent controlling introduced conifers on 4593ha. The report commented that the Group needed to raise at least $500,000 per year to maintain the 12 year plan. Fund raising shortfalls meant that by 2010/2011 (year 4) the programme was underspent by $430,000 and at that rate the programme would not be completed in 12 years. The 2009/10 report also noted that the Ministry for the Environment land had been transferred to LINZ and it was contributing to wilding conifer control funding along with other agencies.

The more recent sources for wilding conifers are the plantings of Douglas fir by farmers on exposed lower western slopes of mid-Dome. These are currently the source of seed and wildings to the area east of mid –Dome (Nick Ledgard, pers. comm.). As long as these plantings remain wildings can be expected to occur in this area on a regular basis.

Information sources: Department of Conservation operational plan 2009-2010, unpublished material from Environment Southland, Richard Bowman of Environment Southland, David Miller from Department of Conservation, Nick Ledgard (formerly Scion), references as listed.

Lessons learnt

- Delays in controlling/ eradicating problem introduced conifer plantings and their wilding offspring can lead to a rapid escalation in costs (from $900,000 in 1999 to $8.5 million in 2008)
- Incomplete or inadequate control achieves little
- Where many different landowners and agencies have land in an area that is affected by wilding conifers co-ordination is essential. This is usually via a group which needs to be formalised if wants to raise revenue.
- Where there is a complex mosaic of land ownership/ management it is helpful to have a combined, agreed strategy and operational plans
- Some historic soil conservation plantings were, in spite of good intentions, unnecessary and ineffective. Scientific investigations are providing us with a better understanding of New Zealand's geology and other natural processes and what types of soil conservation interventions might be appropriate/ inappropriate in different locations
- Managers can be slow to stop planting species that are known to spread
- It can be very difficult to obtain the funding needed to control large dense infestations of wilding conifers
- Even where major control programmes are in place new sources of wilding conifers can develop. For example, recent plantings of Douglas-fir on farms immediately to the west of Mid Dome are an increasing source of seed and wildings within the Mid Dome control area.

20.11.6 Wakatipu wilding conifer control- a community group, district council and the Department of Conservation working together

Introduced conifers were first planted in the Wakatipu area in the 1870s and have grown well, especially on cooler and moister south-facing sites. The conifer-clad slopes that provide the backdrop to Queenstown are the result of plantings and deliberate seeding of Douglas fir from the 1940s to 1960s and the natural regeneration since that time (Day & Ledgard 2009). Part of the original intention for planting was probably to provide Queenstown with protection from rock-falls and avalanches, and to provide cover on what was then perceived as a bare landscape (Day & Ledgard 2009).

In 1986 local councils established a 140ha commercial Douglas fir plantation on the slopes between Coronet Peak and Arrowtown (Day & Ledgard 2009). This area and as well as other smaller plantations, shelterbelts and pockets of established wildings are providing seed sources for the ongoing establishment of wildings in the Wakatipu area.

Day and Ledgard (2009) identified the spreading conifer species in the Wakatipu catchment with the dominant wilding conifer species being Douglas fir. Other vigorous spreading species were Corsican and Scots pine and European larch. They described a cohort of outlier trees in many parts of the catchment that probably established from seed spread in wind events in 1979 and 1981; and reported significant new invasions (e.g. western faces of Remarkable Ranges, north faces of Cecil Peak) probably resulting from increased seed production from maturing stands on “take-off” sites to the west of Queenstown. Contorta pine was present in low numbers in a number of locations, but increasing.

The Department of Conservation began wilding conifer control in the area in the late 1980s. Queenstown Lakes District Council responses to community requests that Council control the spread of wilding conifers and discourage activities that could create additional seed sources included:

- Using rules in the district plan to restrict the planting of various or all conifer species in particular zones/ locations (Appendix 7);
- Commissioning the first Wakatipu Wilding Control Strategy in 2004.

The purpose of that strategy was to promote co-ordinated interagency control of wilding conifers. Following the end of the implementation period (30 June 2008) a revised strategy was prepared for 2008-2012 (Day & Ledgard 2009).

The review of the 2004-2008 strategy found that control work had been carried out in 37(80%) of the management units (MUs). Within those MUs which received funds, it was estimated that removals achieved an average of 65% (range 10-120%) of that needed for containment or effective control (Day & Ledgard 2009). The 2004-2008 strategy focused on removing conifers from sites that had not been cleared before. A significant portion of the budget in the 2008-2012 strategy was for revisiting sites previously cleared prior to coning and before they grew too large for hand-removal. The next highest priority was to remove scattered outliers from clear areas (*Stitch-in-time-saves-nine*). It was noted that while the 2004-2008 strategy had been successful in achieving its overall aims and that funding available to Department of Conservation and Queenstown Lakes District Council had been greater than budgeted, resources were insufficient to complete all high priority

areas and to remove contorta pine. In recognition of the rising costs for control (66% since 2004) Day and Ledgard (2009) recommended that Queenstown Lakes District Council increase their funding for wilding conifer control to $120,000/yr and to make substantial progress the collective agencies raise $1 million in one year.

One further recommendation by Day and Ledgard (2009) was to increase public awareness and buy-in from agencies and landowners by establishing a formal active Wakatipu Wilding Conifer Group. The Wakatipu Wilding Conifer Control Group (WWCCG) was established as a registered charitable society in 2009 with the overall purposes of:

- Sourcing funding to control and contain the spread of wilding conifers within the Wakatipu district,
- Implementing/ recommending updates to the Wakatipu Wildling Conifer Strategy (2008-2012)

The Group has a volunteer list of 307 people, and during 2010-2011 volunteers gave 1741 hours (at an estimated cost of $108, 143). The Council provides administrative support and in 2010-2011 its annual grant to the Group was $127,000. This grant helps the Group leverage funding from other sources. In total the Group raised and spent $260,337 in the 2010-2011 year (including the Council contribution, other grants and sponsorship). The Group has a good working partnership with the Department of Conservation so that finance, technical skills and other resources can be used most cost-effectively. There are also a number of partnerships with landowners and land managers and now LINZ also contributes to the Group. As at the end of the 2010-2011 year Otago Regional Council had not responded positively to the Group's request that they form a partnership on wilding conifer management.

In the 2010-2011 year Department of Conservation and the WWCCG collectively spent $628,500 controlling wilding conifers on 10,332ha of land in the Wakatipu Basin.

Information sources: WWCCG 2010-2011 annual report, Wakatipu wildling conifer control strategies, Briana Pringle of Queenstown Lakes District Council), the references listed

Lessons learnt:

- The establishment of a community-based organisation with partnerships with landowners and agencies (excluding Otago Regional Council) has led to the involvement of more people in wilding conifer management and access to increased resources
- The annual grant and professional management services provided to the WWCCG by the Queenstown District Council provides credibility to the Group and assists them in obtaining more funding
- Otago Regional Council is unusual (for a Regional Council) in not wanting to partner with a broad-based community wilding conifer control organisation nor to collaborate with agencies involved in controlling wilding conifers in their region

20.11.7 Pukaki Downs Station alternative approaches to managing wilding conifers that spread from Crown legacy plantings

Early farm plantings on the western shore of Lake. Pukaki contained contorta pine which had begun to spread prior to the raising of the lake. Remnants of these contorta pine plantings and spread were present after the lake was raised in the early 1970s (Nick Ledgard, pers. comm.). In addition, as part of the Mackenzie Basin power scheme development during the 1970's and 1980's over one million trees were planted in the area by the Ministry of Works and Development (Ledgard & Baker 1997). This included trees planted to slow lake-shore erosion and for amenity purposes. While the Ministry had earlier decided not to plant contorta pine, it appears to have been a "contaminant" in mixed pine plantings in locations such as those around the shores of Lake Pukaki and a major source of wildings in this area (Nick Ledgard, pers. comm.).

The manager of Pukaki Downs had estimated that the cost of removing the wilding conifers (contorta pine) from Pukaki Downs Station would be $4 to $5 million over 20-30 years. As most of the property has been certified as organic (through Bio Grow) only mechanical methods of control could be used. A variety of potential income sources had been investigated as possible ways of earning money to fund the wilding conifer removal. Until the advent of the Emissions Trading Scheme (ETS), no suitable funding sources had been found.

Pukaki Downs Station has now registered a contorta pine containment area for carbon credits under the ETS. Associated with this registration is a management plan to manage the registered area to replace the wilding trees with non-spreading species and to remove wilding conifer spread outside of this area. The revenue earned from the ETS is being used to remove wilding conifers outside of the registered containment area and for planting a wide buffer of non-spreading tree species around the containment area. As it will be some years before the new buffer trees will be tall enough to form an effective buffer that is intended to largely prevent further spread of contorta pine seed, the Station purchased mechanical mulching equipment to clear large areas of juvenile conifer growth outside of the containment area. 340hectares were cleared in 2010, largely using this mulching equipment. Mulching is a chosen method because the property is largely organic and much of the area is being replanted in alternative species. Experience elsewhere has shown that regrowth from cut stems that have retained some green foliage and new wildings growing from seed left behind, requires careful follow-up control if mulching is to be successful long-term (Nick Ledgard, pers. com).

Once the buffer is fully established and tall enough to significantly reduce contorta pine seed spread, the next stage will be to eradicate any remaining wilding conifers outside the containment area and to progressively replace the trees in the registered forest area with alternative species that have a low risk of spread. Potential options for using the contorta pine (e.g. biofuel) as it is removed will be investigated.

It is, however, acknowledged by the Pukaki Downs owners that the full removal of wildings /replacement of all contorta pine will be a long-term (many decades) commitment. The opportunity to get regular income from carbon credits will assist them to achieve this long-term goal.

This case study demonstrates how funding from the ETS could be used to remove wilding conifers using a staged approach based on a management plan. However, some other landowners with wilding conifers are registering areas of wilding conifers in the ETS without plans or intentions of using the ETS funding to remove wilding conifers. In these cases the wilding conifers are unlikely to be replaced by species with a lower risk of spreading. Wildings will continue to spread from the area registered and the resultant progeny elsewhere.

Information sources: Nick Ledgard (formerly Scion); Elaine Curin and Blake Foster of Pukaki Downs Station, references cited.

Lessons learnt

- The ETS can provide a potential long-term funding source for the containment and then progressive removal of wilding conifers from a property by systematically replacing the wilding trees in the containment area with species with a lower risk of spread.
- The ETS can also fund the retention of wilding conifers without a requirement for those wildings to be retained, nor progressively replaced by other species with a lower risk of spreading. The inappropriate use of the ETS could lead to the increase in wilding conifer spread in some areas (possibly even adjoining properties that are using ETS funding to remove wilding conifers). ETS and Biosecurity outcomes may be optimised if registration of tree weeds under the ETS is restricted to those situations where there is:
    - an enforceable management plan requiring that all wilding conifer spread beyond the registered area be prevented;
    - a requirement that a non-spreading tree buffer is planted around the registered area; and
    - a requirement that the tree weeds in the registered area are progressively replaced by non-spreading tree species.

20.11.8 Case study references

Burns B, Williams P, Fitzgerald N 2001. Review of the *Pinus contorta* control programme, Waiouru Military Training Area. Report prepared for the Waiouru Military Camp, New Zealand Army.

Landcare Research Contract Report LC00001/151, Landcare Research. 20 p.

Day C, Ledgard NJ 2009. Wakatipu wilding conifer strategy. Prepared for Queenstown Lakes District Council. Queenstown and Christchurch, Go-Green Consulting and Scion. 100 p.

Fromont M 2008. Rapid review of vegetation succession at Waiouru Military Training Area and implications for training and environmental management. Prepared for the New Zealand Defence Force, Waiouru. 17 p.

Hogg JT, Garrett JW 1975. The eradication of *Pinus contorta.* Waiouru Military Reserve. Rangitikei-Wanganui Catchment Board report (unpublished). (Cited in Burns et al. 2001).

Kingett Mitchell 2004. Scrub management plan, Waiouru Military Training Area. Prepared on behalf of the New Zealand Army (cited in Fromont 2008).

Ledgard NJ 1999. The spread of exotic conifers at Mid Dome/ Cupola, Southland. Prepared for Mid-Dome Wilding Tree Management Group, Southland Regional Council. Christchurch, Forest Research. 21 p.

Ledgard NJ, Baker GC 1997. Management options for introduced trees on Ruataniwha Farm, aound Lakes Tekapo, Pukaki and Ruataniwha, and within the Tekapo, Pukaki and Ohau Rivers. Prepared for Land Information New Zealand. Rangiora, New Zealand Forest Research Institute. 14 p.

McSaveney MJ, Davies TRH 2001. The former Mid Dome Soil Conservation Reserve, Southland: likely consequences to land stability of removal of wilding trees. Institute of Geological and Nuclear Sciences Client Report, project number 43068D, Prepared for the Ministry for the Environment. 15 p.

Mid Dome Wildling Trees Charitable Trust 2008. 12 year wilding tree eradication programme. A blueprint for ecological recovery, Mid Dome Wildling Trees Charitable Trust. 21 p.

Wardrop TN 1964. Reconnaisance survey of the occurence of *Pinus contorta* on the Waiouru Military Reserve. New Zealand Forest Service, Forest Research Institute, Forest Management Branch Report No 1. 37 p.