FORUM ARTICLE

New Zealand's exotic plantation forests as habitats for threatened indigenous species

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Abstract: The contribution of exotic plantation forests to the conservation of New Zealand's flora and fauna is a somewhat controversial issue, partly because the establishment of some plantations involved the conversion of indigenous vegetation. Such conversion no longer occurs within the professional forest industry and there is a growing appreciation of the contribution of 'production' land, including plantation forests, to the protection of New Zealand's unique indigenous biodiversity. This paper provides a comprehensive synthesis of information currently available on threatened species known to occur in New Zealand's plantation forests. Based on an evaluation of the published literature, unpublished reports, national threatened species databases, and personal observations we have compiled records of 118 species classified by the Department of Conservation as threatened that occur in plantations. Of these species, 16 are classified as 'Nationally Critical', 17 'Nationally Endangered' and 17 'Nationally Vulnerable', while the majority are classified as either in 'Gradual Decline', 'Sparse' or 'Range Restricted'. We highlight the direct and indirect benefits of plantations to various threatened taxa and draw attention to the missed conservation opportunities that are generated by a lack of understanding and the somewhat 'puritanical' views of New Zealand's mainstream conservation paradigm. We also discuss some of the potential negative consequences of plantations such as their potential function as 'population sinks' and 'ecological traps'. We conclude with a discussion of future research opportunities that aim to improve the conservation value of plantation forests.

Keywords: conservation; fauna; flora; indigenous biodiversity; landscape matrix; *Pinus radiata*; red list

Introduction

The conservation value of production ecosystems in New Zealand has historically been ignored, partly because such areas were perceived to be poor habitat for native species (Norton & Miller 2000). Recently Macleod et al. (2008) challenged this perception by highlighting the conservation value of agricultural landscapes for New Zealand's bird fauna. As with agriculture, the concept that exotic plantation forests can provide biodiversity conservation gains is somewhat controversial (e.g. Potton 1994; Rosoman 1994; Easton 2007). In part, this stems from the fact that some plantations (and most agricultural land) were established via indigenous deforestation. A key rationale for considering exotic plantation forests as habitat for threatened species is their potential role to mitigate historical deforestation within landscapes (Zurita & Bellocq 2010). In prehuman times New Zealand was predominantly forested. However, recent analyses (Leathwick et al. 2003) indicate that remaining indigenous forest cover in many regions is now below the theoretical extinction threshold level, where species viability is predicted to decline following habitat loss of 70–90% (Andrén 1994; With & King 1999). Today, exotic plantations cover c. 7% (1.8 million hectares) of New Zealand (MAF 2009), and constitute a significant proportion of the forest cover in some regions (Ewers et al. 2006). The New Zealand plantation forest industry is predominantly managed as even-aged monoculture stands of *Pinus radiata* (89% of all plantings; Anon. 2007) that are typically harvested by clear-felling at stand ages between 26 and 32 years. *Pseudotsuga menziesii* (Douglas-fir) is the second most common species (6.4% of total plantings), with *Eucalyptus*, *Cupressus* and other *Pinus* species planted in smaller amounts. Large-scale intensive management is the predominant forestry model in New Zealand, which includes a significant emphasis on pre-planting site preparation. Site preparation includes movement of harvest slash, soil disturbance as frost protection, i.e. mounding, and the use of broad-spectrum residual herbicides before planting.

Plantations currently represent c. 20% of New Zealand's total forest area and are the largest areas of privately owned forest. However, the area of plantation forest has recently decreased as a result of large-scale agricultural conversions in the central North Island and Canterbury that began in 2004. This process was driven by a purely economic assessment of land-use profitability combined with a 'perverse' deforestation incentive caused by the implementation of Kyoto Protocol deforestation penalties. By contrast, the positive contribution of plantations and their provision of surrogate habitat for biodiversity (Allen et al. 1995; Ogden et al. 1997; Berndt et al. 2008; Pawson et al. 2008), enhanced connectivity between indigenous forest remnants, and ecological buffers from adjacent non-forest land uses (Norton 1998; Denyer et al. 2006; Brockerhoff et al. 2008a) were largely ignored. Some 45 200 ha of plantation forest, an area larger than Egmont National Park, was cleared between 2005 and 2008 (MAF 2009).

By drawing together a comprehensive synthesis of information about threatened species in New Zealand's plantation forests we provide evidence that challenges the notion that conservation of threatened forest-dwelling species should remain the preserve of publicly owned indigenous ecosystems. We show that threatened species do occur in plantations, and propose that land use planners and policymakers should consider the conservation opportunities provided by the mix of commercial stands and native ecosystem remnants that constitute a plantation forest. In-depth case studies are given to highlight the current and future prospects of specific threatened species within plantations. We discuss the potential direct and indirect values of plantation habitat for threatened species, and identify shared ecological traits of species that unhabit plantations. We also outline potential negative consequences of plantation forestry associated with inappropriate afforestation, the periodic severe habitat disturbance (i.e. clear-fell harvesting), and the risks of plantations potentially acting as ecological traps. Finally, we suggest future research directions required if we are to maximise the opportunities for threatened species in managed exotic plantations.

Methods

We define a plantation as the total forest estate managed by a forestry company or other landowners, including stands of commercial timber tree species and their embedded indigenous vegetation remnants. Records of threatened species in plantation forests were collated from the New Zealand Freshwater Fish Database (NIWA); Bioweb database: Herpetofauna and Threatened Plants (Department of Conservation); unpublished reports from Wildland Consultants, Scion (New Zealand Forest Research Institute), and several forestry companies; student theses; a comprehensive search of scientific literature; and personal observations by the authors and others (see Acknowledgements). Where relevant, herbarium voucher specimens are given, e.g. NZFRI 2784 refers to a specimen in the National Forestry Herbarium, Scion; AK is Auckland Museum Herbarium; and CHR is the Allan Herbarium, Lincoln. Threatened avifauna (Miskelly et al. 2008) and flora (de Lange et al. 2009) were included, based on the threat classification of Townsend et al. (2008). Other fauna were included in this review as they were ranked by Hitchmough et al. (2007) on the basis of the threat classification system by Molloy et al. (2002). Records from national databases were spatially cross-referenced with the New Zealand Landcover Database (LCDB2, Terralink) and overlaid with the plantation forest classes (class numbers 64–66: Forest Harvested, Pine Forest – Open Canopy, Pine Forest – Closed Canopy, respectively) using ArcMap 9.2 (ESRI, USA), to identify potential records within habitat defined as exotic plantation forest in 2001–02. Relying on LCDB matches for land cover information is potentially error-prone, as observations may have been made prior to plantation establishment, and because classification errors are known to exist in underlying LCDB data (Brockerhoff et al. 2008b). Therefore, historical records were individually checked and only those where land tenure was confirmed to be plantation forest at the time of the survey are presented here. In several cases, observers were contacted to verify records that appeared to be potentially incorrect.

Results and Discussion

A total of 118 threatened species (as per Hitchmough et al. 2007; Miskelly et al. 2008; de Lange et al. 2009) have been recorded or observed within plantation estates (Table 1). Of these species, 54 were recorded from within exotic forest stands (Appendix 1) and 44 species have only been observed in the managed indigenous forest remnants, wetlands, and frost flats that are embedded within plantation estates (Appendix 2). An additional eight reptile species have been recorded from plantations, but it is unknown what habitat they are using. At least 20 species (predominantly plants) are known to have been negatively affected by plantations (by mechanisms such as reductions in population size and, in some cases, localised extinction), although this is likely to be a significant underestimate as most adverse effects that occurred due to past exotic afforestation were not recorded. Plantations contribute to the conservation of 16 species ranked as 'Nationally Critical', 17 'Nationally Endangered', and 17 'Nationally Vulnerable'. However, most species that benefit from plantations as a habitat are currently classified as 'Declining', 'Range Restricted', 'Sparse' or 'Naturally Uncommon' (Table 1).

Direct benefits from plantation stands as habitat for threatened species

Plants

Vascular plants are the dominant group of threatened plants known to occur in plantation forests. Currently there is little information available on threatened non-vascular plants in New Zealand plantation forests, although at least two liverworts, *Schistochila pellucida* and *Lophozia pumicicola* (both Nationally Critical), and one moss

Table 1. Number of threatened species known to occur in plantation forests. Threat categories are those assigned by Miskelly et al. (2008) and Hitchmough et al. (2007) for fauna, and de Lange et al. (2009) for plants. Letters in brackets after threat categories correspond to the second column in Appendix 1.

	Threat classification (Molloy et al. 2002)							
	Acutely Threatened			Chronically Threatened		At Risk		
Taxon	Nationally Critical (A)	Nationally Endangered (B)	Nationally Vulnerable (C)	Serious Decline (D)	Gradual Decline (E)	Sparse (F)	Range Restricted (G)	Total
Fish		2	1		7	2		13[1]
Invertebrates	1	3						6[2]
Mammals		1	1					2
Herpetofauna	1				8	1		10
	Threat classification (Townsend et al. 2008)							
	Nationally Critical (A)	Nationally Endangered (B)	Nationally Vulnerable (C)	Declining (D)	Recovering (E)	Relict (F)	Naturally Uncommon (G)	
Birds		1	7				1	9
Plants	14	10	8	20	0	1	24	78[3]
Total								118

[1]Includes one other species defined as Data Deficient, but with human-induced population decline.
[2]Includes two other species of *Peripatus* that are known to be threatened and present in plantations, but currently not classified.
[3]Includes *Acrolejeunea allisonii* that is currently not classified.

(*Zygodon rufescens*, Sparse) have been recorded from New Zealand pine plantations or areas now converted to plantations. Another liverwort species, *Acrolejeunea allisonii,* recorded from the Kaingaroa Plateau, is now considered threatened (P.J. de Lange, DOC, Auckland, pers. comm.) but has not yet been formally classified. They are all species of open, pumice frost-flats that have probably contracted in range due to exotic afforestation of their natural habitats.

Threatened vascular plants recorded in New Zealand's exotic plantations (including embedded indigenous remnants) include 7 ferns, 25 small trees and shrubs, 19 dicot herbs, and 21 monocot herbs. This diversity of species reflects (1) the favourable microclimate beneath a canopy of plantation trees that allows the development of a diverse understorey layer of shade-tolerant forest plants (Allen et al. 1995; Ogden et al. 1997; Brockerhoff et al. 2003), (2) the periodic disturbance due to harvesting that creates early successional habitat for ruderal species (although few threatened ruderal species are recorded for New Zealand, many have been recorded overseas; see Eycott et al. 2006), and (3) the wide range of natural habitats included as indigenous remnants within areas managed as plantation forests (e.g. *Christella* aff. *dentata* (b) (AK 126902; 'thermal') associated with thermal springs in plantations near Rotorua). About half of New Zealand's threatened indigenous plants occur in historically rare ecosystems (Williams et al. 2007) and often have extremely localised distributions. Given that exotic plantation forests have been planted throughout New Zealand in different climates and on many different landforms and soil types, it is not surprising that a wide range of threatened plants present prior to planting have been retained in some plantations. However, when plantations are converted to pasture they are unlikely to retain such native plant assemblages, given the impact of stock grazing and the poor diversity of native plants that are known to survive under a regime of high intensity pastoral agriculture (Ecroyd & Brockerhoff 2005).

Orchids (case study)

The first records of indigenous orchids in plantations are from Kaingaroa Forest in the 1940s (e.g. herbarium vouchers NZFRI 2784, NZFRI 3590). Subsequently, in the 1970s, 'thousands' of ground orchids were recorded in the plantations of North Canterbury (Thompson 1970; Elder & Moore 1973). In 1981, the importance of Hanmer Forest as a site for indigenous orchids was realised with the discovery of the vagrant bird orchid *Simpliglottis valida* (syn. *Chiloglottis valida*) (Molloy 1992). In 1985, a larger population of this species (rare in New Zealand) was discovered under *Pinus nigra* stands at Iwitahi, southern Kaingaroa Forest (Molloy 1992). Iwitahi is a nationally important orchid site; about 24% (c. 40 species) of the New Zealand orchid flora is recorded from there, including three species classified as Sparse: *Stegostyla atradenia* (syn. *Caladenia atradenia*), *Thelymitra formosa,* and the red-bearded orchid, *Calochilus robertsonii* (Gibbs 1988; Ecroyd 2008). In 1986, after discussions with the New Zealand Forestry Corporation, a reserve covenant was placed on a small (5 ha) area of 50-year-old *P. nigra*, which was set aside from felling. Orchids thrive at Iwitahi because over-maturity and attacks of the needle cast fungus, *Dothistroma* have caused the *P. nigra* canopy to open and allow more light to reach the forest floor as well as providing a thick mat of pine needles that creates ideal conditions for orchid growth (Gibbs 1988).

Today, except for the small orchid reserve, virtually all the old *P. nigra* stands near Iwitahi have been logged, cleared and replanted with *P. radiata*. Although, the dense forest canopy and a thinner layer of leaf litter in *P. radiata* do not support the same diversity of orchids as that found at Iwitahi, significant new finds of highly threatened orchids, such as *Thelymitra sanscilia,* have been made in *P. radiata* stands. The internal plantation forestry road reduces many logistical impediments to studying the population ecology of threatened species, such as orchids. A detailed assessment of orchid community composition across a range of tree species, stocking density, and pruning regimes would enhance our understanding of native orchid ecology. Such information would facilitate better conservation management of these species in plantations and indigenous forests.

Mammals

Roosting of Nationally Vulnerable long-tailed bats (*Chalinolobus tuberculata*) in plantation forests was first reported from a stand near Lake Arapuni, Tokoroa, in 1976 (Daniel 1981). Since that time, field surveys using ultrasonic detectors and radio telemetry have shown that long-tailed bats feed and roost extensively in stands of *P. radiata* and *Eucalyptus* spp., as well as indigenous reserve areas within Kinleith Forest (Moore 2001; Borkin & Parsons 2009). Bats utilise stand roads and stream edges for feeding and as commuting routes. Little is known about short-tailed bats in plantations, although the northern subspecies (*Mystacina tuberculata aupourica*) has been recorded in indigenous remnants adjacent to, and embedded within plantations; however, there are only anecdotal reports of them utilising plantation forests (Lloyd 2001; Moore 2001).

Birds

Birds were the focus of some of the earliest ecological studies in New Zealand plantations (Ryder 1948; Gibb 1961; Clout & Gaze 1984). Insectivores are the most common guild of birds found in plantations, whereas few nectar- and fruit-feeding species are present in pine plantations (Clout 1984). However, nectar-feeding species may be temporarily abundant in eucalypt plantations, particularly during the flowering period (Clout 1984). Kōkako (*Callaeas cinerea*) utilise plantation forests as an extension of feeding territories (Innes et al. 1991), but they have not been recorded as breeding in plantation stands. Likewise, large flocks of up to 20 North Island kākā (*Nestor meridionalis septentrionalis*, an indigenous forest-dwelling parrot) have been observed in central North Island plantations (RS, pers. obs.), where they have been seen feeding extensively on sap in Douglas-fir stands (Beaven 1996). The long-tailed cuckoo (*Eudynamys taitensis*) is a nest parasite that is gradually declining throughout New Zealand although it has followed its host, the whitehead (*Mohoua albicilla*), into many central North Island plantation forests.

Kiwi (case study)

North Island brown kiwi (*Apteryx mantelli*) and the great spotted kiwi (*A. haastii*) both occur in plantations. Formally recorded for the first time in the early 1970s (Corbett et al. 1979), kiwi inhabit the full plantation forest matrix, including mid-phase and mature exotic stands, newly planted sites, slash piles, windrows, log piles on skid sites, and indigenous remnants. North Island brown kiwi is the most common kiwi species associated with plantations. Significant known populations are present in plantations in Northland, Coromandel, Tongariro, and Hawke's Bay, and smaller localised populations are also present in the Bay of Plenty (Pierce & Shaw 2003, unpubl. Wildland Consultants client report). Waitangi State Forest (a plantation) has been the focus of intense kiwi research and, in the 1980s, the population was estimated at 800–1000 (Colbourne & Kleinpaste 1984), the largest recorded at that time in any type of habitat (Taborsky 1988).

The range and abundance of kiwi continue to decline throughout New Zealand, due largely to the combined effects of adult and chick mortality, from predation by mustelids, dogs, and pigs, as well as possum traps, and natural causes (Heather & Robertson 2005). One of the best documented cases of such predation was the impact of a single stray dog in Waitangi State Forest that killed up to 500 North Island brown kiwi (Taborsky 1988). In addition to predator impacts, forest harvesting remains a threat to kiwi survival in plantation forests, particularly during the breeding period. However, recognition of the importance of plantations for kiwi conservation is increasing. Recently, management guidelines (http://rarespecies.nzfoa.org.nz/fauna/forest_birds/species/kiwi.htm) were produced for plantation owners to increase awareness of threatened species, to reduce the impact of forest management activities, and to increase kiwi populations, for example by advising that tree felling is minimised during the kiwi breeding season.

The relatively widespread distribution of kiwi (and other native birds) within plantations allows tests of current and emerging ideas in conservation biology, for example, theories of matrix permeability between indigenous and production habitat, connectivity, and the genetic diversity of metapopulations.

New Zealand falcons (case study)

The New Zealand falcon is an endemic raptor thought to have been naturally distributed throughout New Zealand (Buller 1888). Due to the synergistic effects of widespread habitat loss, human persecution, and the impacts of exotic predators, the New Zealand falcon is now classified as threatened (Miskelly et al. 2008). Three ecologically distinct forms of the falcon – bush (Nationally Vulnerable), eastern (Nationally Vulnerable), and southern (Nationally Endangered) – occur in New Zealand (Fox 1977). Traditionally, falcons were thought to breed in a variety of habitats, including tussocklands, roughly grazed hill country, and indigenous forest, where they nest on the ground, in cliff cavities, snags of trees, or within the epiphytes of emergent podocarps (Fox 1977; Barea et al. 1997). However, significant breeding populations of all three forms have recently been discovered nesting on the ground in recent clearfells in exotic plantation forest (Stewart & Hyde 2004; Maunder et al. 2005; Addison et al. 2006; Seaton 2007). Some of the highest breeding densities of falcons anywhere in New Zealand have been recorded in Kaingaroa Forest (a pine plantation) in the central North Island (Seaton 2007).

The main factors contributing to the suitability of pine plantations to falcons include high prey density (particularly exotic passerines), optimal hunting conditions, regularly available and abundant nesting habitat, and periodic predator control (Seaton 2007, Seaton et al. 2009). Pest control (primarily targeting possums), in the form of 1080 bait, may have a two-fold benefit for falcons, reducing the number of some species of predators (Gillies & Pierce 1999) and increasing the abundance of prey (Powlesland et al. 1999). Rotational clear-fell harvesting, while promoting high prey density, provides a continuous availability of suitable nest sites in the form of clear-felled pine blocks. It is usually only the large-scale plantations that provide this continuous availability of different-aged stands and clear-felled areas, so currently it is unclear what minimum size of plantation forest is required to support falcon populations.

Falcons and other threatened species in plantations provide the opportunity to test for the presence of extinction thresholds in the availability of habitat in fragmented landscapes. Principally, do plantations mitigate habitat loss and prevent total available habitat from falling below a local extinction threshold? Research from South America would suggest that plantations can reduce localised extinction of bird species to some extent within fragmented landscapes (Zurita & Bellocq 2010).

Invertebrates

Invertebrates are the most species-rich animal group in New Zealand, with an estimated 20 000 species of insects (Emberson 1998) and many thousands of other taxa. Few threatened invertebrates have been recorded in plantations, which partly reflects the lack of adequate sampling. However, many invertebrates have specialised habitat requirements and host associations that contribute to their threat rankings. Because of these strong host associations, many threatened species are unlikely to be found in plantations. Despite this, several species of New Zealand's carnivorous land snails are present in North and South Island plantations. Two subspecies of the Nationally Endangered *Powelliphanta lignaria* are known from indigenous remnants and plantation stands on the West Coast. In addition, *Powelliphanta traversii tararuaensis* is recorded from plantation stands near Shannon (Manawatu). At the latter site, a species-specific management plan was commissioned by the forest owners to ensure the protection of this particular species within their estate (Makan 2007, unpubl. Earnslaw One report).

Most studies of invertebrate diversity in plantations have focused on non-threatened beetle taxa (Hutcheson & Jones 1999; Neumegen 2006, unpubl. BSc Hons thesis, School of Biological Sciences, University of Canterbury; Pawson 2006; Pawson et al. 2008), but one study records a remarkable case of a nationally critically endangered ground beetle, *Holcaspis brevicula*, that is restricted to a plantation forest.

Holcaspis brevicula (case study)

The ground beetle *Holcaspis brevicula* Butcher is an endemic species that occurs only on the Canterbury Plains between the Waimakariri and Ashley rivers (Butcher 1984; Brockerhoff et al. 2005). Almost its entire former forest habitat has been converted to agricultural land uses, and the only remaining forest remnants in this area are small patches of kānuka (*Kunzea ericoides*), most of which are accessed and degraded by domestic stock (Ecroyd & Brockerhoff 2005). The only known remaining population of *H. brevicula* occurs in Eyrewell Forest, a pine plantation that was established in the 1920s on land with poor soils considered unsuitable for agriculture except for 'dry sheep' (Molloy & Ives 1972). Although plantation forestry involves considerable habitat disturbance during tree-felling and site preparation, kānuka and other indigenous plants remained as an understorey at varying densities under much of the pines in Eyrewell Forest (Ecroyd & Brockerhoff 2005). The same has happened with *H. brevicula*, and based on a substantial survey, Eyrewell Forest now harbours the only known remaining population of this beetle (Brockerhoff et al. 2005). Although *H. brevicula* appears to be one of the rarest ground beetles, the population in Eyrewell Forest has survived at detectable levels during the last 80 years of plantation forestry, involving at least three rotations of tree planting and felling. However, this forest, along with several others in this area, is currently being converted to pasture, primarily for dairying. The decision to convert Eyrewell Forest to pasture has been driven by an economic assessment of profitability, with little consideration of biodiversity values. If the conversion is implemented without setting aside adequate areas of suitable habitat for *H. brevicula* (i.e. plantation forest or restored kānuka forest) then this species is likely to become extinct in the near future.

Indirect benefits derived from plantation forestry

Many plantations include significant indigenous remnants and aquatic habitat within their broad boundaries. Some holdings contain up to 20% indigenous vegetation (Wildland Consultants 2002, unpubl. client report), of which parts are formally protected as Forest Accord reserves. Other areas of indigenous vegetation within plantations are managed by agencies such as the Department of Conservation. Obviously indigenous remnants such as these are ecologically different from adjacent commercial plantation stands, and provide a greater range of opportunities for threatened species. In some cases these indigenous remnants may provide the bulk of available habitat for species within a particular landscape, in which case they become even more important. However, to exclude them from a discussion of threatened species in plantations just perpetuates the historical divide New Zealand has made between the production and conservation estate. The majority of privately owned production lands (plantations and agriculture) include 'non-productive' areas within their jurisdiction and land managers should be actively encouraged to maximise potential conservation opportunities. To this end, plantation managers of Forest Stewardship Council (FSC) certified forests are required by the FSC principles and criteria to actively manage native remnants and threatened species throughout their entire plantation estate (including commercial stands). In addition FSC criteria specify a minimum proportion of indigenous ecosystems within certified plantations. Where this is not achieved forest managers are required to restore additional indigenous habitat.

The relative biodiversity conservation value of such 'non-productive' indigenous habitat remnants within plantations as opposed to other human-modified landscapes is a point of debate. Threatened species that utilise indigenous forest remnants within a plantation derive indirect benefits from the plantation stands, such as: (1) availability of additional forest habitat (and associated forest food resources to extend foraging territories) in adjacent plantation stands; (2) buffers that reduce the penetration of microclimatic edge effects in indigenous remnants (Norton 1998; Denyer et al. 2006); (3) protection of in-stream aquatic values, such as incident light and water temperature in older stands (Quinn et al. 1997); (4) in some cases regular biodiversity and forest health monitoring of indigenous remnants by FSC-certified plantation owners (e.g. THE Package; Hosking 2009); (5) exclusion of stock (which are often able to access and graze forest patches in other agricultural land – but grazing is occasionally used to control invasive exotic weeds in some young plantation stands); and (6) periodic pest control for browsing mammals. The overall net conservation benefit of native remnants in plantations is not straightforward, however, and will be highly dependent on the degree and type of active management applied to these indigenous remnants and their surrounding plantation stands.

Some of the potential benefits of plantations are temporal. For example, harvesting is a significant disturbance factor that not only alters the microclimate of adjacent native forest remnants, but can create temporal changes in in-stream aquatic parameters (Morgan & Graynoth 1978; Fahey 1994). Today, most in-stream impacts of harvesting are mitigated by the establishment and protection of riparian vegetation buffer strips designed to separate aquatic ecosystems and riparian vegetation from forest management impacts (Boothroyd & Langer 1999; Harding et al. 2000; Rowe et al. 2002). At present, the maintenance of riparian vegetation is a key performance indicator in the environmental principles of FSC, the New Zealand Environmental Code of Practice for Plantation Forestry (NZFOA 2007), and as a condition for forestry as a permitted activity by many regional councils.

An additional benefit of plantation forestry is the biodiversity monitoring programmes undertaken by many of the large forest-management companies of their indigenous remnants. These have largely been initiated to comply with FSC guidelines. The resulting detailed inventories have led to direct conservation management of indigenous remnants and plantations stands (a practice that should be encouraged). For example, Hochstetter's frog (*Leiopelma hochstetteri*) was found in seepages, streams and riparian areas of embedded indigenous remnants and plantation stands in the Bay of Plenty and Auckland regions. Forestry companies subsequently undertook periodic monitoring of *L. hochstetteri* populations to assess the impacts of harvesting within forest catchments (Douglas 2001, cited in Hall & Jack 2009). In a plantation forest in Rodney District (Northland), an area was set aside from harvesting and retained as a frog sanctuary. A second example of active conservation management linked to biodiversity monitoring concerns the nationally endangered *Clianthus maximus* (kōwhai ngutukākā or kaka beak). Although common in cultivation (where it has a very limited gene pool; Shaw & Burns 1997), wild populations of this species remain extremely scarce, and it is threatened by introduced browsers, particularly feral goats and deer (Shaw 1993; Shaw & Burns 1997). Present in indigenous vegetation in steep gullies on the edge of pine stands in the Hawke's Bay and East Cape regions, this species has benefited from active management (e.g. goat control) by forestry companies that manage these areas.

Ecological traits of species found in plantation forests

It is clear that some groups of threatened species are more likely to use plantations than others. For example, the indigenous bird fauna of plantations is dominated by insectivorous species, with few fruit and nectar feeders (Clout & Gaze 1984; Seaton 2007). This reflects the relative availability of food resources as the commonly planted pines lack nectar and fleshy fruits as they are wind-pollinated and have wind-dispersed seeds. Furthermore, hole-nesting birds are rarely present because the clear-fell harvest regime removes all old trees, largely precluding the development of cavities suitable for nesting.

The majority of threatened plants that occur in plantation stands are those that can complete their life cycle and set seed within the current rotation of 26–32 years. Rotation length has a profound influence on indigenous plant diversity. The species composition of the understorey changes markedly as plantations age, from a dominance of ruderal species to later seral, shade-tolerant plants, primarily of native forest species (Brockerhoff et al. 2003). The latter would benefit from longer rotation lengths. There is perhaps an overrepresentation of plants with wind-dispersed seeds or spores, such as orchids and ferns, some of which, especially the orchids, benefit from an association with the mycorrhizal fungi associated with the plantation trees. However, there are some exceptions to these generalisations and some species seem to find exotic plantations highly suitable as habitat, for as yet unknown reasons.

Adverse effects of plantations

It is clear that plantations (like other modified land uses) can be detrimental to threatened species (and biodiversity in general) especially when they are established at the expense of original indigenous habitat. Fortunately this practice is no longer widespread, although some exotic afforestation of unimproved indigenous grasslands and shrublands continues on a smaller scale, particularly in Otago. Furthermore, the increasing pressure to establish plantations on suboptimal (marginal) agricultural land represents a potential lost opportunity to re-establish indigenous forests that could provide greater long-term conservation benefits.

Unintended afforestation of suboptimal agricultural land or indigenous grasslands, shrublands and forests is of major concern. This manifests from the 'wilding' spread of planted exotic conifers and currently threatens c. 400 000 ha throughout New Zealand (Ledgard 2004). However, the role of plantation forestry in this process should be placed in context as a large number of 'wilding' conifer infestations are not the result of plantation forestry but the product of poorly conceived soil erosion control efforts, or the establishment of shelterbelts on farms. This is not to say that plantation forestry has not contributed to the problem. Today known invasive species such as *Pinus contorta* and *P. nigra* are not widely planted for timber purposes, the most notable exception to this is Douglas-fir, which is more shade tolerant than pines and has a proven ability to invade native forest ecosystems, particularly those subject to disturbance (Ledgard 2002).

In addition to the direct effect of habitat replacement, plantations may create population sinks or ecological traps. A population sink refers to habitat that cannot support a self-sustaining population, but which relies on immigration from adjacent habitat (Pulliam 1988). An ecological trap refers to a specific type of population sink, where individuals make poor habitat choices based on misleading environmental cues that can result in reduced breeding opportunities or mortality (Schlaepfer et al. 2002). Neither concept has been tested explicitly in New Zealand plantations, but exotic forest plantations provide the ideal macrocosm to test large-scale source–sink population dynamics in forest ecosystems. Furthermore the ability to manipulate forest harvesting schedules allows replicated experimental tests of forest disturbance processes and their subsequent impacts on population dynamics within forests, and between forests and other modified production ecosystems. What we do know from available avifaunal data is that there are significant populations of the endangered North Island brown kiwi (Kleinpaste 1990) and New Zealand falcon (Seaton 2007), as well as thriving populations of non-threatened insectivorous birds, such as North Island robins (*Petroica australis longipes*), fantails (*Rhipidura fuliginosa*), pied tits (*Petroica macrocephala toitoi*), and whiteheads (Clout & Gaze 1984; Seaton 2007; Deconchat et al. 2009). The high-density self-perpetuating nature of these populations suggests that immigration from adjacent native forest is not required to maintain these populations. Where population dynamics have been studied in depth, both the NI brown kiwi and NZ falcon were shown to breed prolifically in plantations (Kleinpaste 1990; Seaton 2007), and, in the case of falcons, to have productivity greater than that recorded from other habitat types.

It is conceivable that plantations could present an ecological trap for some groups of species in New Zealand, particularly as 'traps' are known to occur more frequently in highly modified environments (Schlaepfer et al. 2002). To our knowledge, there are no confirmed cases of ecological traps in New Zealand plantations; however, examples are known from managed forests elsewhere (Flaspohler et al. 2001; Robertson & Hutto 2007). Two possible ecological traps that may be operating and which require further research are: (1) colonisation by saproxylic insects of wood that is removed some time after felling and (2) ruderal species using plantation stands as habitat. Saproxylic insects could experience an ecological trap if harvest residues are to be used increasingly for bioenergy (Hedin et al. 2008). However, it is uncertain whether this would affect any threatened saproxylic invertebrates in New Zealand. Plantation stands can provide adequate habitat for ruderal species such as *Myosurus minimus* subsp. *novae-zelandiae* (mouse tail), *Pomaderris hamiltoni*, and *P. rugosa* that prefer disturbed ground such as that found in recent clearfells. However, recent clearfells provide suboptimal habitat for these species because they are likely to be eliminated by the use of broad-spectrum herbicides prior to replanting. Such an ecological trap would only operate for one year as plants colonising stands after herbicide treatment will benefit from favourable conditions for longer periods. Although, like all early-successional habitat, clearfells are temporary and subsequently disappear with canopy closure as stands age. The clear benefit of plantations for ruderal and early seral species is that new disturbed habitat, in the form of recent clearfells, is continuously created throughout large plantation estates, and such plants are well adapted to the colonisation and existence in temporary habitats.

Potential contributions to restoration ecology

Exotic plantations present an opportunity to attempt the reintroduction of some indigenous species to regions where they have become regionally extinct. The North Island robin, pied tit, and whitehead are common in exotic plantations in the central North Island, but the whitehead and robin have disappeared from northern New Zealand and the pied tit is scarce through much of Northland and the Waikato (Robertson et al. 2007). North Island robins from abundant plantation populations have already been used in translocations to re-establish populations in indigenous reserves (e.g. from Waimarino Plantation to the nearby Paengaroa Mainland Island (NZ Translocation Database 2008), with some success). However, insectivorous birds are obviously well suited to plantations and there is merit in assessing indirect translocation approaches where individuals are translocated to plantation forests that adjoin indigenous forest areas where pest control is being implemented, in an attempt to increase translocation success. Further research is necessary to determine if native bird populations in plantation forests are indeed self-sustainable irrespective of immigration from natural habitat remnants.

Future research: Improving plantations for conservation values

Future research efforts need to focus at two distinct spatial scales: (1) how fine-scale silvicultural management influences habitat suitability for threatened species and (2) how to manipulate landscape-scale habitat features to enhance conservation values across entire plantations and wider landscapes.

Fine-scale silvicultural management includes site preparation (movement of harvest debris, herbicide use, and soil mounding), pruning, stocking, and crop species selection (including mixtures). In New Zealand we know that specific management actions can benefit particular threatened species, e.g. clearfell edges provide foraging habitat for New Zealand falcons (Seaton 2007). However, we need a better understanding of how current management practices limit colonisation by threatened species, and what is required to overcome this. For example, does the movement of harvest debris and herbicides prevent native plant species from colonising recent clearfells, or can site preparation methods be refined to create favourable sites for native seedling establishment while not inhibiting exotic replanting? Can greater populations of nectar- and fruit-feeding bird species be supported by enhancing understorey plant diversity by oversowing within existing plantations, or by creating new mixed species plantations? Do high stumps and other legacy features used to preserve saproxylic beetles in Europe (Lindhe & Lindelöw 2004) have the potential to provide habitat for species reliant on old-dead trees, e.g. cavity-nesting birds?

At larger scales, landscape heterogeneity is an important determinant of conservation values in plantation forests. The concept of landscape heterogeneity includes the proportion of, and proximity to, native forest habitats, as well as the spatial juxtaposition of different-aged plantation stands (Lindenmayer & Hobbs 2004). In New Zealand plantations we need to determine how aspects of landscape heterogeneity affect the conservation biology of mobile and immobile taxa as stands grow and are harvested. Two critical aspects to investigate are: (1) what resources do species require from different-aged stands, and how far can species disperse to capitalise on these? In doing so, can the size and spatial arrangement of different-aged stands be optimised to significantly increase the conservation value of existing plantations? and (2) is there a relationship between the proportion of native habitat within and around plantations and the population viability of particular threatened species, and if so, how should native habitat be provided? Single large areas of native habitat are likely to retain more native species as predicted by the species–area relationship. However, across large plantations, a network of smaller patches, riparian and roadside strips that maximise proximity of native habitat to production stands may provide greater conservation benefits, especially if the plantation stands are subject to ongoing pest control and this ‘overlaps’ with the indigenous habitats.

An underlying feature of threatened species research in New Zealand plantations is a lack of general biodiversity surveys and a centralised repository for recording both threatened and common native species. Although basic inventory is not a lofty goal, any research undertaken in plantations should make the effort to record basic information, including species names, locations, and a description of stand characteristics (minimum of tree species and age). We encourage researchers to incorporate such data into a national framework and suggest the New Zealand Biodiversity Recording Network. By including the keyword ‘plantation’ in the ‘purpose’ field, the long-term accumulation of data could eventually reveal how silvicultural factors influence conservation values over larger scales in different climatic and biogeographic regions.

Conclusions

Exotic plantation forests have become an integral and large-scale component of the New Zealand landscape. Plantations provide substantial areas of lowland habitat suitable for many forest-adapted species. However, large areas of these exotic forests have recently been converted to agricultural pasture, which does not support most forest-dwelling species. We recorded 118 threatened species within plantations but the total is undoubtedly much greater, due to the lack of survey effort and the difficulty in accessing data (e.g. finding old file notes and contract reports). A better reporting system to collate biodiversity records from plantations is urgently needed to facilitate information access and to enable opportunities for threatened species management. There has been some progress in our understanding of the contribution of plantation forests to the conservation of diverse assemblages of indigenous species and habitats. Nevertheless, it is clear that research is urgently required to quantify the full suite of benefits to threatened species and other elements of our native biodiversity within these plantations, before more are converted to non-forest land uses and to maximise conservation benefits, as new carbon forest plantations are likely to be created on marginal land.

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Appendix 1. Threatened species recorded from plantation forests. Threat classifications are those assigned by Miskelly et al. (2008) for birds, Hitchmough et al. (2007) for other fauna, and de Lange et al. (2009) for plants. Threat categories refer to abbreviations in Table 1 (1. = Not threatened, although this ranking is qualified as 'Data Deficient' and human-induced population reductions; 2. = Taxonomically uncertain, many species declining due to habitat degradation). Habitat use refers to: A. species present in plantation stands, B. species present in remnants of indigenous vegetation within plantation estates, and C. species that are known to have been negatively affected by the establishment of plantations.

Threatened species	Threat category	Geographical area	Habitat use	Plantation species (when known)	Source
Birds					
Apteryx mantelli (North Island brown kiwi)	C	Northland; Coromandel; central North Island; Bay of Plenty; inland Hawke's Bay	A,B	*Pinus radiata*	Maunder et al. 2005
Apteryx haasti (great spotted kiwi)	C	West Coast	A,B	*Pinus radiata*	NZFOA, pers. comm.
Callaeas wilsoni (North Island kōkako)	C	Bay of Plenty	A,B	*Pinus radiata*	Innes et al. 1991
Nestor meridionalis septentrionalis (North Island kākā)	C	Kaingaroa; Whirinaki; central North Island	A,B	*Pinus radiata, Pseudotsuga menziesii*	Beaven 1996; RS, pers. obs.
Falco novaeseelandiae sensu stricto (bush falcon)	C	Large North Island pine forests south of Auckland; Golden Downs, Nelson; possible South Island localities	A,B	*Pinus radiata & Pseudotsuga menziesii*	RS, WBS, & D. Cooper, pers. obs.
Falco novaeseelandiae 'eastern' (Eastern falcon)	C	Canterbury; Otago; large forests in central South Island	A,B	*Pinus radiata & Pseudotsuga menziesii*	NZIF[1] members, WBPT[2], Raptor Association of New Zealand
Falco novaeseelandiae 'southern' (Southern falcon)	B	Large Southland pine forests	A,B	*Pinus radiata & Pseudotsuga menziesii*	NZIF[1] members, WBPT[2], Raptor Association of New Zealand
Eudynamus taitensis (koekoea, long-tailed cuckoo)	G	Central North Island; East Coast	A,B	*Pinus radiata & Pseudotsuga menziesii*	Pierce et al. 2002, unpubl. Wildland Consultants client report
Mammals					
Mystacina tuberculata aupourica (Northern short-tailed bat)	B	Central North Island	A?,B	?	Lloyd 2001 Moore 2001
Chalinolobus tuberculata (long-tailed bat, North Island)	C	Central North Island; Waikato	A,B	*Pinus radiata & Eucalyptus* spp.	Daniel 1981; K. Borkin, pers. comm.
Fish					
Neochanna burrowsius (Canterbury mudfish)	B	Canterbury	A?,B	*Pinus radiata*	Harding & McIntosh 2006; Harding et al. 2007
Neochanna heleios (Northland mudfish)	B	Northland	A?,B	*Pinus radiata*	NZ Freshwater Fish Database
Neochanna apoda (brown mudfish)	E	Manawatu; Wairarapa; West Coast	A?,B	?	NZ Freshwater Fish Database
Neochanna diversus (black mudfish)	E	Ngatihine Forest, Northland	A?,B	?	NZ Freshwater Fish Database
Galaxias argentus (giant kōkopu)	E	Waikato; Coromandel; Bay of Plenty; East Cape; Taranaki; West Coast; Southland	A,B	?	Hanchet 1990
Galaxias eldoni (Eldon's galaxias)	C	Otago	A,B	?	NZ Freshwater Fish Database
Galaxias depressiceps (flathead galaxias)	E	Coastal Otago Forests; Dunedin	A,B	?	NZ Freshwater Fish Database
Galaxias fasciatus (banded kōkopu)	1.	Waikato; Coromandel; Bay of Plenty; Hawke's Bay	A,B	*Pinus radiata*	Hanchet 1990; Rowe et al. 1999; Hicks & McCaughan 1997
Galaxias postvectis (shortjaw kōkopu)	F	West Coast; Marlborough; Manawatu; Taranaki; Bay of Plenty; East Cape	A,B	?	NZ Freshwater Fish Database

Threatened species	Threat category	Geographical area	Habitat use	Plantation species (when known)	Source
Galaxias pullus (Dusky galaxias)	E	Otago	A,B	?	NZ Freshwater Fish Database
Galaxias divergens (dwarf galaxias)	E	Wellington; Nelson; Marlborough; West Coast	A,B	*Pinus radiata* & *Pseudotsuga menziesii*	Graynoth 1979
Anguilla dieffenbachia (longfin eel)	E	Extensive; Southland; Canterbury; Westland; Nelson/Marlborough; throughout North Island	A,B	Various	NZ Freshwater Fish Database
Geotria australis (lamprey)	F	Coromandel; Taranaki; Wairarapa; West Coast; Coastal Otago; Southland Forests	A,B	*Pinus radiata*	Jowett & Richardson 2003; NZ Freshwater Fish Database; Rowe et al. 2002
Invertebrates					
Holcaspis brevicula	A	Canterbury	A	*Pinus radiata*	Brockerhoff et al. 2005
Peripatus spp.	2.	Wanganui; Wellington	A?,B	*Pinus radiata*	D. Gleeson, pers. comm.
Peripatus spp.	2.	Mamaku; Coromandel	A	*Pinus radiata* & *Eucalyptus* sp.	D. Gleeson, pers. comm
Powelliphanta lignaria rotella	B	West Coast	A,B	*Pinus radiata* & *Pinus muricata*	K. Walker and Timberlands West Coast, pers. comm.
Powelliphanta traversi tararuaensis	B	Manawatu	A,B	*Pinus radiata*	Makan 2007, citing from Ecological Networks Client Report No. 70
Reptiles					
Naultinus gemmeus (jewelled gecko)	E	Canterbury	?	?	Ecological regions and districts of New Zealand, booklet to accompany sheet 3.
Naultinus elegans elegans (Auckland green gecko)	E	Waikato; Northland; Bay of Plenty	?	?	BioWeb: Herpetofauna
Naultinus elegans punctatus (Wellington tree gecko)	E	Wellington	?	?	BioWeb: Herpetofauna
Oligosoma lineoocellatum (spotted skink)	E	Canterbury; Nelson	?	?	BioWeb: Herpetofauna
Oligosoma infrapunctatum (speckled skink)	E	Waikato; Nelson	?	?	BioWeb: Herpetofauna
Oligosoma chloronoton (green skink)	E	Southland	?	?	BioWeb: Herpetofauna
Naultinus rudis (rough gecko)	E	Canterbury	?	?	BioWeb: Herpetofauna
Hoplodactylus pacificus (Pacific gecko)	E	Northland	?	?	BioWeb: Herpetofauna
Plants[3]					
Anogramma leptophylla	C	Eastern Wairarapa; Canterbury	A,B	*Pinus radiata*	BioWeb TPD[4]
Calochilus robertsonii	G	Central North Island	A	*Pinus nigra* & *Pinus radiata*	BioWeb TPD[4]; Ecroyd 2008
Carex inopinata	B	Marlborough; Canterbury; Southland	A,B	*Pinus radiata*	BioWeb TPD[4]; N. Head & B. Rance, pers. comm.
Carmichaelia crassicaulis subsp. *crassicaulis*	D	Otago	C	*Pinus radiata*?	J. Barkla, pers. comm.
Carmichaelia kirkii	D	Canterbury	C	?	N. Head, pers. comm.
Carmichaelia torulosa	B	Canterbury	C?	?	BioWeb TPD[4]
Celmisia adamsii var. *rugulosa*	G	Whangarei	C	?	BioWeb TPD[4]
Celmisia hookeri	G	Otago	C?	?	BioWeb TPD[4]
Centipeda minima	A	Northland	A,B	?	P. de Lange, pers. comm.

Threatened species	Threat category	Geographical area	Habitat use	Plantation species (when known)	Source
Corunastylis nuda	G	Eastern Wairarapa	A,B	*Pinus radiata*	BioWeb TPD[4]; de Lange et al. 2007
Dactylanthus taylorii	C	Taranaki; central North Island	A,B	*Pinus radiata*	Ecroyd 1995
Daucus glochidiatus	A	Northland	A	*Pinus radiata*	P. de Lange pers.comm.
Eleocharis neozelandica	D	Northland; Great Barrier Island; Manawatu	C	?	BioWeb TPD[4]; C. Ogle and P. de Lange, pers. comm.
Gingidia grisea	G	Otago	C	?	J. Barkla, pers. comm.
Hypolepis dicksonioides	G	Northland; Taranaki	A	*Pinus radiata*	BioWeb TPD[4], WELT P20853
Linguella puberula	A	Nelson; Southland	C	*Pinus radiata*	S. Courtney, pers. comm.
Melicytus aff. *alpinus* (b) (CHR[6] 541565; Rangipo)	B	Central North Island; Canterbury	C	*Pinus radiata* & *Pseudotsuga menziesii*	Rooney 1986 [as *M. crassifolius*]; Norton 1989; N. Singers, pers. comm.
Myosurus minimus subsp. *novae-zelandiae*	A	North Canterbury; Otago	A	*Pinus radiata*	BioWeb TPD[4]; NZFRI[7] 3553
Olearia polita	B	Nelson	C	?	S. Courtney, pers. comm.
Peraxilla colensoi	D	Marlborough; Southland	A,B	*Pinus radiata*	B. Rance, pers. comm
Petalochilus bartlettii	G	Central North Island	A	*Pinus nigra*	CEE, pers. obs.
Petalochilus variegatus	G	Central North Island	A	*Pinus nigra*	CEE, pers. obs.
Picris burbidgeae	B	Northland; Coromandel	A?	*Pinus radiata*	BioWeb TPD[4] P. de Lange, pers. comm.
Pimelea actea	A	Manawatu	C	?	Burrows 2008
Pimelea tomentosa	C	Auckland; Central North Island	A,B	*Pinus radiata*	BioWeb TPD[4]; NZFRI[7] 21185
Pittosporum turneri	C	Central North Island	A,B	*Pinus contorta, Pinus ponderosa*	CEE, pers. obs.
Pomaderris hamiltonii	G	Great Barrier Island; Northland	A,B	*Pinus radiata*	BioWeb TPD[4]
Pomaderris rugosa	G	Coromandel; Waikato	A,B	*Pinus radiata*	BioWeb TPD[4]; NZFRI[7] 18898.
Pterostylis foliata	G	Central North Island	A	*Pinus nigra*	CEE, pers. obs.
Schistochila pellucida	A	Central North Island	A,B,C	*Pinus radiata*	P. de Lange, pers. comm.
Stegostyla atradenia	G	Central North Island	A	*Pinus nigra*	BioWeb TPD[4]; NZFRI[7] 16718
Stuckenia pectinata	G	Manawatu	A	*Pinus radiata*	BioWeb TPD[4]
Thelymitra formosa	G	Central North Island	C	*Pinus nigra*	Ecroyd 2008
Thelymitra sanscilia	A	Northland	A	*Pinus radiata*	P. de Lange, pers. comm.
Todea barbara	B	Northland	A,B,C	*Pinus radiata*	BioWeb TPD[4]; NZFRI[7] 13435
Townsonia deflexa	G	Central North Island	A	*Pinus nigra*	N. Singers, pers. comm.
Urtica aspera	G	South Canterbury	A	?	BioWeb TPD[4]; CHR[6] 188736
Urtica linearifolia	D	Central North Island	A,B	*Pinus radiata*	BioWeb TPD[4]; J. Hobbs, pers. comm.

[1]WBPT= Wingspan Birds of Prey Trust
[2]NZIF= New Zealand Institute of Forestry
[3]Unless referenced, botanical names follow: Allan Herbarium (2000) Ngā Tipu o Aotearoa – New Zealand Plant Names Database. Landcare Research, New Zealand. Available http://nzflora.landcareresearch.co.nz/ (accessed June 2008).
[4]BioWeb TPD* = Department of Conservation Threatened Plant Database
Herbaria: [5]WELT = Museum of New Zealand – Te Papa Tongarewa, Wellington
[6]CHR = Allan Herbarium, Landcare Research, Lincoln
[7]NZFRI = National Forestry Herbarium, Rotorua

Appendix 2. Threatened species recorded from indigenous remnants managed as part of a plantation forest estate. Threat classifications are those assigned by Miskelly et al. (2008) for birds, Hitchmough et al. (2007) for other fauna, and de Lange et al. (2009) for plants. Threat categories refer to abbreviations in Table 1. Case study classifications refer to: A. species present in plantation stands, B. species present in remnants of indigenous vegetation within plantation estates, and C. species that are known to have been negatively affected by the establishment of plantations.

Threatened species	Threat category	Geographical area	Habitat use	Plantation species (when known)	Source[1]
Birds					
Hymenolaimus malachorhynchos (blue duck, whio)	C	Inland Hawke's Bay; King Country	B	?	W. Shaw, pers. obs.
Invertebrates					
Powelliphanta lignaria johnstoni	B	West Coast	B	?	K. Walker and Timberlands West Coast, pers. comm.
Frogs					
Leiopelma hochstetteri (Hochstetters frog)	F	Northland; East Cape; Coromandel; Bay of Plenty	B	*Pinus radiata*	C. Zinsli, N. Gemmel, L. Douglas & A. Smale, pers. comm., BioWeb: Herpetofauna & Wildland Consultants
Leiopelma archeyi (Archey's frog)	A	Coromandel	B	*Pinus radiata*	BioWeb: Herpetofauna Database
Plants					
Acrolejeunea allisonii	Not yet listed	Central North Island	B,C	Frost flat vegetation	P. de Lange, pers. comm.
Carex tenuiculmis	D	Southland	B	?	BioWeb TPD; S. Courtney & B. Rance, pers. comm.
Carex uncifolia	B	Southland	B	*Pinus radiata*?	BioWeb TPD; B. Rance, pers. comm.
Carmichaelia carmichaeliae	A	Marlborough	B	?	BioWeb TPD
Christella aff. *dentata* (b) (AK[2] 126902; 'thermal')	D	Central North Island	B	*Pinus radiata*	BioWeb TPD
Clianthus maximus	A	East Cape; Hawke's Bay	B	*Pinus radiata*	NZFRI 20229; Shaw & Burns 1997
Coprosma obconica	D	Nelson; Marlborough	B,C	?	BioWeb TPD; S. Courtney, pers. comm;
Coprosma wallii	D	Marlborough; Southland	B	?	BioWeb TPD; B. Rance, pers. comm.
Coriaria pottsiana	G	East Coast	B	?	BioWeb TPD
Crassula ruamahunga	G	Wanganui	B	?	de Lange et al. 2008.
Cyclosorus interruptus	D	Northland; Bay of Plenty; Waikato;, Central North Island.	B	?	BioWeb TPD; CEE pers. obs.; P. de Lange, pers. comm.
Deschampsia cespitosa	D	Southland	B,C	?	B. Rance, pers. comm.
Gratiola concinna	C	Central North Island; Southland	B	?	N. Singers & B. Rance, pers. comm.
Hebe speciosa	C	Auckland	B	?	BioWeb TPD
Iphigenia novae-zelandiae	C	North Otago	B	?	BioWeb TPD; J. Barkla, pers. comm.
Isolepis basilaris	B	Canterbury	B	?	BioWeb TPD
Korthalsella salicornioides	G	Northland; Wairarapa; Marlborough	B	?	BioWeb TPD
Lobelia aff. *angulata* (AK[2] 212143; Woodhill)	A	Auckland	B	?	BioWeb TPD
Lophozia pumicicola	A	Central North Island	B,C	*Pumice frost flats*	P. de Lange, pers. comm.
Mazus novaezeelandiae subsp. *impolitus* f. *impolitus*	C	Manawatu	B	?	J. Campbell, pers. comm.
Melicytus flexuosus	D	Central North Island; Southland	B,C	*Pinus radiata, Pinus contorta &*	BioWeb TPD; CEE, pers. obs.; D. Norton, pers. comm.

Threatened species	Threat category	Geographical area	Habitat use	Plantation species (when known)	Source
				Pinus ponderosa	
Olearia fragrantissima	D	Dunsdale Stream, Southland	B	?	B. Rance, pers. comm.
Olearia lineata	D	Otago; Southland	B	?	J. Barkla & B. Rance, pers. comm.
Peperomia tetraphylla	G	East Cape	B	?	BioWeb TPD
Pimelea arenaria	D	Northland; Bay of Plenty	B,C	?	BioWeb TPD; NZFRI 19999
Plumatichilos tasmanicum	B	Coromandel	B	?	P. de Lange, pers. comm.
Pomaderris phylicifolia	B	Northland	B	?	P. de Lange, pers. comm.
Prasophyllum hectorii	F	Central North Island	B	?	BioWeb TPD
Pseudopanax ferox	G	Auckland; Marlborough	B	*Pinus radiata*	BioWeb TPD
Pterostylis micromega	A	Central North Island; Wanganui	B	?	BioWeb TPD
Ptisana salicina	D	South Auckland	B	?	P. Cashmore, pers. comm.
Ranunculus 'Hope' (a) (CHR[3] 573506; Hope)	A	Nelson	B	?	BioWeb TPD; S. Courtney, pers. comm.
Ranunculus ternatifolius	G	Central North Island; Nelson; Southland	B	?	BioWeb TPD; B. Rance, pers. comm.
Schoenus fluitans	D	Tangiwai Bog, Central North Island	B	?	BioWeb TPD
Scutellaria novae-zelandiae	A	Nelson	B	?	BioWeb TPD; S. Courtney pers. comm.
Teucridium parvifolium	D	Marlborough; Canterbury	B	?	BioWeb TPD
Thelypteris confluens	D	Northland; North Auckland	B	*Pinus radiata*	BioWeb TPD; P. de Lange, pers. comm.
Thismia rodwayi	G	Central North Island	B	?	N. Singers, pers. comm.
Tupeia antarctica	D	Central North Island	B	?	N. Singers, pers. comm.
Zygodon rufescens	G	Central North Island	B,C,	*Frost flats*	P. de Lange, pers. comm.

[1]BioWeb TPD = Department of Conservation Threatened Plant Database; NZFRI = National Forestry Herbarium, Rotorua
[2]AK = Auckland War Memorial Museum
[3]CHR = Allan Herbarium, Landcare Research, Lincoln