Manaaki Whenua
Landcare Research

Stocktake of resources and databases for managing the invasive plants of New Zealand

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Murray I Dawson

Manaaki Whenua – Landcare Research

Reviewed by:

Angela Brandt

Ecologist / Modeller / Capability Leader
Manaaki Whenua – Landcare Research

Approved for release by:

Geoff Ridley
Portfolio Leader – Biota
Manaaki Whenua – Landcare Research

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Summary

Project and client

- The Parliamentary Commissioner for the Environment (PCE) has embarked on an investigation into the current management of invasive plants in New Zealand.
- The scope of the wider investigation by the PCE identified the need to commission a stocktake of existing resources and databases, with the focus on invasive plants.
- Manaaki Whenua – Landcare Research (MWLR) was contracted to provide this stocktake as a concise report to the PCE.

Objectives

- Provide definitions of terms used to describe weeds and invasive plants.
- Provide a stocktake of resources, including key issues and constraints relating to the management of invasive plants.
- Describe how the resources fit into invasive plant management and how they are used.

Methods

- Assemble a list of resources used for invasive plant management.
- Provide evidence-based analyses of these resources.
- Fact-check by consulting with experts in their relevant roles.

Discussion: Invasive plant resources and databases

Resources from three categories are discussed, including:

- technical databases and data stores:
    - New Zealand Organisms Register
    - Ngā Tipu o Aotearoa – New Zealand Plants names database
    - Plants Biosecurity Index
    - Unwanted Organisms Register
- description, identification and management tools:
    - floras and e-floras
    - keys, interactive keys and smartphone apps
    - field guides, booklets and invasive plant websites
    - Regional Pest Management Plans
- outreach, citizen science and social media:
    - Department of Conservation, regional council and Crown Research Institute outreach
    - iNaturalist NZ
    - Facebook groups.

Conclusions and key issues

Many resources are available for managing invasive plant species in New Zealand, and they have been evaluated and analysed in this report. The key issues and constraints relating to these resources for invasive plant management are:

- lack of efficient management of plant names between organisations
- some resources overlap and are duplicated
- some resources are missing or scattered due to multiple custodians with mixed interconnections and several categories of (and terminology for) invasive plants / pest plants / weeds.

Underpinning these key issues are funding constraints, as well as lack of agility, lack of coordination and shared goals/strategies among the many players, and legislative issues.

Recommendations

- Encourage recognition of MWLR's New Zealand Plants names database and the New Zealand Organisms Register as the primary sources of scientific names for New Zealand, and advocate for their ongoing resourcing.
- Seek a high-level solution to connect the New Zealand Organisms Register's names infrastructure to the Ministry for Primary Industries' regulatory and unwanted species resources, including the Plants Biosecurity Index, the Unwanted Organisms Register, and the National Pest Plant Accord.
- Create a new resource that integrates and delivers clearly defined categories of invasive plants in one place, including Department of Conservation environmental weeds, regional councils' Regional Pest Management Plan species, National Pest Plant Accord species, and the International Union for Conservation of Nature New Zealand invasive plant list.

1 Introduction

Invasive plants are plants that are not native to a specific location and have an ability to spread to a degree believed to cause damage to the environment, the economy or human health.

Invasive plants are expensive to manage and can cause irreversible damage to ecosystems. They represent a major problem in Aotearoa – New Zealand (NZ). Weed control has been estimated to cost NZ $1.3 billion in losses for the pastoral sector, $18 million for the arable sector, and $333 million for the forestry sector annually (Saunders et al. 2017).

A range of often overlapping terminology is used to describe invasive plants, such as invasive alien species (IAS), environmental weeds, and pest plants (clarified in the Glossary, section 8).

NZ, like other countries, has various invasive plant management strategies, both pre-border and post-border, that attempt to control or at least mitigate the economic and ecological impacts of invasive species. Three examples of resources associated with management strategies are the Plants Biosecurity Index (PBI), the National Pest Plant Accord (NPPA), and Regional Pest Management Plans (RPMPs).

These and other resources have been created by several organisations at different times for various purposes, including databases, identification and management tools, and citizen science platforms.

These resources are invariably grouped by organisation. For example, MWLR maintain the New Zealand Organisms Register (NZOR), Ngā Tipu o Aotearoa – New Zealand Plants names database (PND), the online e-flora, and several interactive identification keys; while MPI Biosecurity NZ are responsible for maintaining the PBI, the NPPA, and the Unwanted Organisms Register (UOR). The degree of connection between these resources within, and especially between, organisations and custodians is mixed.

The core element shared by all invasive plant resources (the 'unique identifier') is the botanical name. Correct (internationally accepted) botanical names and correct identifications (what the identity of the organism actually is) are essential to align these resources and provide consistency.

This report provides a stocktake of these resources in order to gain insights into how they are managed, how they function, and how they contribute to invasive plant management in NZ.

2 Objectives

The objectives of this report are to:

- provide definitions for and clarify the various terms used to describe weeds and invasive plants
- provide a stocktake of resources, and evidence-based analysis and insights into key issues and constraints facing databases and other resources as they relate to the management of invasive plants
- describe and illustrate how different resources and databases fit into invasive plant management, and how they are used by different players/organisations for different purposes.

3 Methods

A glossary of terms and definitions for weeds and invasive plants was assembled by the author (see Glossary, section 8). These were sourced from online and print media, and definitions considered to be clear and accurate were selected and edited as required.

An initial list of resources and databases used for invasive plant management was assembled by the author of this report based on past experience. Several additions were made to this list following feedback from PCE staff and consultation with other experts.

A summary table template was constructed, in collaboration with PCE staff, to provide evidence-based analyses of these resources. These summary tables included 23 fields for each resource, such as:

- purpose/rationale
- development and maintenance
- data content:
    - scope
    - strengths
    - weaknesses
- user base
- relationship to other resources.

Each table, corresponding to one resource, was pre-populated with the aim of achieving consistency and objectivity.

The draft summary tables were then emailed to the primary contacts/custodians of each resource for fact-checking and feedback. Included for comparison were summary tables of closely related resources the custodians were not responsible for. Feedback was incorporated and the summary tables aggregated in Appendix 1.

This information provided the basis from which to identify commonalities, disconnects, key issues, and constraints.

4 Discussion: Invasive plant resources and databases

Although there are overlaps in function, the resources provided in Appendix 1 fall into three main categories:

- authoritative technical databases and data stores supporting research and regulation, for a relatively narrow user base, broader in scope than, but including, invasive plants
- description, identification and management tools, some of which are dedicated to invasive plants
- outreach, citizen science, and social media, to engage with a wide audience, including the general public, on invasive plants.

4.1 Technical databases and data stores

The technology behind modern databases has come a long way in recent years. Data are able to be interconnected and explored in ways that were not possible two or three decades ago.

Although some of the specialist databases profiled here may have relatively narrow user bases, they are nevertheless of high value to those who do use the authoritative and extensive resources they contain.

Why do scientific names matter? Effective management of invasive species is dependent on their correct identification (what the organism is) and accurate naming (what the accepted scientific name for that organism is, and other names by which it has been known). Common (vernacular) names on their own are unreliable for managing invasive species, because they can be ambiguous, and one common name can apply to several different species.

Since about 2000, MWLR has led the development of interconnected, highly structured and authoritative scientific name and collection databases in NZ. These provide online access to nationally significant collection data[1] and were created through the collaboration of systematics and bioinformatics teams at MWLR, primarily through the vision of Aaron Wilton, Jerry Cooper and Nick Spencer.

MWLR databases relevant to invasive plants include the:

- New Zealand Organisms Register (NZOR), a dynamic catalogue of taxonomic names of NZ biota
- Ngā Tipu o Aotearoa – New Zealand Plants (PND), a plant names database delivering referenced, scientific and common names of the NZ flora

[1] Collectively recognised as Nationally Significant Databases and Collections (NSDCs), a status first accorded in 1998 by the former Foundation for Research, Science and Technology.

- Systematics Collections Data (SCD), specimen and culture data from nationally significant collections, including Allan Herbarium specimen data
- New Zealand National Vegetation Survey (NVS) databank, NZ's repository for ecological data on vegetation structure and composition.

The NZOR and PND deliver scientific names in a managed database infrastructure, while the SCD and NVS databases (and data stores such as the NZ Non-native Flora Traits & Distributions) provide granular information (such as individual specimen label data and species recorded in plots) used for research and big-data analyses.

All four databases are publicly accessible and interconnect names with other data. Data from these resources are structured following best-practice international biodiversity information standards (TDWG). Adherence to data standards allows federation to international databases.

For example, NZ herbaria specimen data are provided to the Australasian Virtual Herbarium (AVH). Through the AVH users can simultaneously search NZ and Australian herbaria records for a plant taxon, including invasive species, to retrieve specimen collection and distribution data.

More inclusive is the Global Biodiversity Information Facility (GBIF), which aggregates extensive data sets from many countries. GBIF receives NZ data from herbaria, the NVS, iNaturalist, and other data sets such as a recent NZ contribution to the Global Register of Introduced and Invasive Species (GRIIS) (Champion et al. 2019). These combined data make the GBIF repository a powerful resource for importing, exploring and exporting biodiversity data, including distribution data.

For example, AgResearch and collaborators have used CLIMEX software and spatial data of invasive plant species extracted from GBIF to generate 'hotspot' maps of the current and predicted spread of Chilean needle grass (*Nassella neesiana*), tall buttercup (*Ranunculus acris* subsp. *acris*), and yellow bristle grass (*Setaria pumila*), demonstrating a powerful tool for IAS management in NZ and worldwide (Bourdôt et al. 2010; Bourdôt et al. 2013; Lamoureaux & Bourdôt 2014; Graeme Bourdôt, pers. comm.).

NZOR is an innovative platform that provides information services and a continuously updated catalogue of taxonomic names of all NZ biota (plants, fungi, animals, insects, etc.). It has integrated extensive names concept data from providers (including MWLR, NIWA, Te Papa, and DOC), and exchanges plant names data with other MWLR databases/services such as the PND. Much potential remains to dynamically interconnect NZOR to resources outside MWLR in order to achieve less duplication and better management of names for NZ biota, including invasive plant species.

The PND was developed to indicate which names are preferred for use at the Allan Herbarium (CHR). Nevertheless, as discussed later in this report, there is a strong case for

recognising the PND and NZOR as the primary and most authoritative sources for accessing scientific names, including those of invasive plants, in NZ[2].

Biosecurity New Zealand, part of the Ministry for Primary Industries (MPI), hosts databases that help them to meet their biosecurity responsibilities. Those relevant to invasive plants include the:

- Plants Biosecurity Index (PBI), which manages biosecurity requirements of plant material, such as import health standards[3] for seed and nursery stock, and listing unwanted organisms and prohibited species

- Unwanted Organisms Register (UOR), with categories of unwanted pests, including invasive plants and diseases.

These MPI resources are built on older database architecture, and neither of them follow international biodiversity information standards (TDWG). As a consequence, the taxonomic name handling does not follow best practice. For example, there are no author authorities (standard author abbreviations for the botanist/s associated with describing a taxon), references (publication details for names, including date and journal), and few synonyms (a history of alternative names). Lack of this supporting information can create uncertainty about the correct identity of the taxa – what name refers to which plant.

Biosecurity NZ emphasises the utility of the PBI for managing import standards, rather than the widely held, end-user, horticulturist view that it is a list of all plant species present in NZ. This mismatch in perception is a source of frustration to the plant production industry when they seek to import material, because the PBI is what is used at the border to confirm the status of a species as 'new' or 'not new' under the Hazardous Substances and New Organisms (HSNO) Act 1996. For this reason, the PBI is considered by plant importers and producers as not fit for purpose (New Zealand Plant Producers Incorporated, pers. comm.), because it is incomplete and lacks associated data by which to validate names.

Although the PBI is the most comprehensive online listing of plants considered not to be new organisms under the HSNO Act 1996, there are also issues if names missing from the PBI trigger investigations of growers propagating plant material that is legally in NZ but not listed. Presence in NZ determinations made by the Environmental Protection Authority (EPA) are not automatically added to the PBI, or any other external database, which creates further data disconnects.

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[2] However, the existing taxonomic/nomenclatural resources are typically prioritised on the NZ indigenous flora. Correct names/concepts for invasive plants can get left behind. A case could be made that global initiatives such as Plants of the World online, or the World Flora Online are beginning to provide a degree of global consensus.

[3] Import health standards are legal documents issued under section 24A of the Biosecurity Act 1993. These standards include the biosecurity requirements that commodities must meet before biosecurity clearance can be given and the consignment can be successfully imported into NZ (www.mpi.govt.nz/importing/overview/import-health-standards/).

There is also scope for improvement in MWLR's plant names databases. They contain leading data coverage for NZ native plant taxa, good data for fully naturalised taxa, but patchy coverage for cultivated-only exotic taxa[4].

Predominantly northern hemisphere taxa exotic to NZ are treated comprehensively in international databases such as the GBIF, International Plant Names Index (IPNI), Plants of the World online and World Flora Online (WFO). Conversely, names for Australasian native taxa (from the NZ PND and the Australian Plant Census) are poorly treated in those resources. The obvious solution is to exchange names data with these resources in order to 'flag' then reconcile name changes to improve their respective data quality and maximise efficiencies.

Of higher priority in NZ is the potential for connecting MWLR's plant names database infrastructure with MPI's biosecurity requirements, as detailed in 'Conclusions' (section 5).

DOC maintains a weeds database which is a subset of their BioWeb databases. These resources are primarily for DOC's internal use throughout NZ. The DOC weeds database has a web interface and usefully draws together diverse information that overlaps with other resources, such as biostatus, botanical and common names (also found in MWLR's plant names databases), herbarium and distribution records (also in the AVH and GBIF), chemical control methods (also in AgPest, Massey University Weeds Database, and Weedbusters NZ), and images found in several other resources. Because the DOC weeds database is not available to the public (except by formal application, as a 'DOC associate'), this stand-alone database is not profiled in Appendix 1. Further details of this resource are available from DOC (Clayson Howell, pers. comm.).

International plant names databases and overseas lists of invasive species are referenced in this report, but only NZ resources are profiled in Appendix 1. These international databases include:

- Global Biodiversity Information Facility (GBIF)
- Global Compendium of Weeds (GCW)
- Global Invasive Species Database (GISD)
- International Plant Names Index (IPNI)
- Plants of the World Online (POWO)
- The Plant List (TPL)
- World Flora Online (WFO).

[4] Cultivated-only taxa are important for invasive plant management because they represent the greatest source of new naturalisations in New Zealand, as emphasised in Philip Hulme's 2018 Leonard Cockayne Lecture series.

4.2 Description, identification and management tools

Hosting plant names (nomenclature) in databases is different from the description and identification of taxa (taxonomy). Accurate and rapid identification is essential for managing invasive species. For example, many biological control (biocontrol) agents are highly specific to one species or even one genotype of the invasive plant targeted for control. If the invasive plant is not correctly identified and named, then the prospective biocontrol agent is likely to fail. Time and expense may thus be wasted, involving government approvals, collecting prospective biocontrol agents from other countries, importing and raising them in containment in NZ, host testing them, and then, following further approvals, releasing them in the wild.

4.2.1 Floras and e-floras

Traditional floras, monographs and revisions date from the time of Carl Linnaeus, the 'father of modern taxonomy' in the 1700s, and they remain highly relevant as primary and authoritative information sources. Floras, monographs and revisions encompass many years of research by professional botanists, using both classical and modern techniques (such as molecular systematics) to resolve the relationships between and identities of plant groups. Floras contain comprehensive and detailed descriptions and dichotomous keys from which to identify plant taxa.

The NZ printed floras that are most relevant to invasive plants cover monocots (Healy & Edgar 1980), grasses (Edgar & Connor 2010), and naturalised ferns, conifers, and dicots (Webb, Sykes & Garnock-Jones 1988). Only two of these authors are alive today, and both retired decades ago. This highlights a serious decline in taxonomic expertise and capacity. Since the early 1990s the introduction in NZ of contestable funding models that favour new and short-term projects do not create research environments or infrastructure support (e.g. libraries in Crown Research Institutes) conducive to the long-term research required to produce these specialised floras[5].

Fortunately, the old printed Flora of New Zealand series has been digitised and is freely available online (https://floraseries.landcareresearch.co.nz/pages/Index.aspx). The original botanical descriptions have been repackaged in the more useful nzflora (Flora of New Zealand Online) website (www.nzflora.info). The nzflora website publishes and incorporates new flora contributions called fascicles. Most of the new online revisions have concentrated on 'lower' plants (ferns and lycophytes by P.J. Brownsey & L.R. Perrie of Te Papa; mosses by A.J. Fife of MWLR, now retired). This delivers a pragmatic, 'publish-as-you-go' approach, but, because of limited resources, little attention is being given to new revisions for 'higher' plants (such as flowering plants and conifers), which contain the

[5] For example, the recent production of three volumes of a liverwort and hornwort flora of New Zealand has only been possible through full-time voluntary work by a retired research associate in Chicago and part-time hours by a New Zealand taxonomist. The flora has been published in the USA and few copies are available in New Zealand.

majority of invasive species. Minor errors in the original printed flora descriptions have not been prioritised for correction in the nzflora website which has led to them being perpetuated in derived works.

There are obvious overlaps in the indigenous and naturalised species profiles found in MWLR's nzflora online pages and those of the New Zealand Plant Conservation Network. (www.nzpcn.org.nz/flora/species). Online descriptions derived from the printed floras are virtually identical. In addition, both organisations produce complete lists of taxa for indigenous and naturalised plants. No matter how the authors may justify it, this approach produces competing resources and duplication of effort.

4.2.2 Keys, interactive keys and smartphone apps

In addition to technical descriptions, printed floras contain traditional identification keys. These are dichotomous, meaning they have a single starting point and guide users through a fabricated path of two choices each time to (hopefully) arrive at a correct identification. It can be difficult for a user to figure out the correct choices to make, and it is often said that these keys are 'written by those who don't need them for those who can't use them'. Furthermore, dichotomous keys often rely on floral characters as being the most informative, so if the specimen being identified is not in flower then the key will fail to complete an identification.

Online interactive keys have many advantages over traditional dichotomous keys: they are multi-access (meaning that a user can start anywhere and select any characters they like); they are powerful, efficient and easy to use (e.g. with built-in explanations and images of characters and character states); and they can accommodate numerous images (from which to help confirm identifications).

The Identic developers based in Queensland, Australia, are recognised as leaders in key building software, which they have trademarked as Lucid™ software. Researchers from several countries have used Lucid software to produce online keys and smartphone identification apps. Several relevant to invasive plants are 'Environmental Weeds of Australia', 'Weeds of Australian Cotton', 'Weeds of South East QLD and Northern NSW', and 'Federal Noxious Weeds Key' (United States Department of Agriculture).

For identifying plants in NZ, MWLR[6] has produced about 10 browser-based Lucid keys (www.landcareresearch.co.nz/resources/identification/plants). Those most relevant to invasive plants are three large interactive keys: 'Key to flowering plant genera of New Zealand' (native and naturalised), 'Key to the grasses of New Zealand' (native and naturalised), and especially the 'Key to the weed species of New Zealand' (Appendix 1). MWLR has also produced keys specialising in two genera that contain weedy species: *Cotoneaster* and *Salix* (willows).

[6] It should also be noted that MWLR provide a plant identification and information service, utilising their botanical expertise, databases, and the resources of the Allan Herbarium and DNA diagnostic services. Clients include regional councils, the EPA, MPI, and the general public.

Due to their portability and increased processing power and storage capacity, smartphones have become the device of choice worldwide. There are thousands of productivity apps available for smartphones, including identification tools. The Lucid interactive key developers (Identic) have created scripts to redeploy output from their key builder software into 'LucidMobile' smartphone apps. This has the major advantage of using the same data files as the browser-based keys, meaning they share a common platform and don't have to be built from scratch.

SCION, MWLR and DOC have collaborated to produce an early access LucidMobile 'NZ Wilding Conifers' app to identify wilding confers in NZ. MWLR and collaborators have completed two LucidMobile versions of their online keys, both of them for native plants (coprosmas and native orchids). However, there is no LucidMobile rendering of the MWLR online key to weed species of NZ, which prevents easy use of this key in the field to identify invasive plants. The nearest equivalent – which shares some images, character state scores and architecture – is the 'Environmental Weeds of Australia' app.

Lucid online and smartphone interactive keys are powerful and accurate, but they are a teaching tool with a moderate learning curve, requiring users to spend time understanding characters in order to make accurate identifications and use the tool effectively. Like all keys, interactive keys are constrained by the set of organisms contained within them (e.g. the online key to weed species of NZ contains more than 650 weeds, but many common weeds are still missing from this resource).

A different approach is taken by the iNaturalist smartphone app, which (like the browser interface) effectively employs both machine image recognition and community identifications. Relying only on image recognition has mixed success for identifications, ranging from very accurate to completely wrong matches. Images can also be misidentified as species absent from NZ, as the machine recognition draws from an international pool of images.

The related 'Seek' app relies on machine image recognition only, drawing on the extensive image library accumulated by iNaturalist contributors[7]. Seek provides a solution for NZ (regional council and MPI) plant pest and incursion officers who want quick identifications of invasive plants with details that may need to be kept confidential. Seek was originally developed by the iNaturalist team as a kids-friendly app (to exclude personal profiles and online conversations). The 'Find-A-Pest' app was developed for regional biosecurity surveillance of pests and weeds. This NZ reporting tool feeds approved data into the iNaturalist platform but does not currently feature image recognition. The Australian developed 'QuestaGame' app relies on the iNaturalist platform for community identifications.

Other popular plant identification apps, not specific to NZ, include 'Pl@ntNet Plant Identification' and 'PlantSnap – plants, trees and flowers identifier'.

[7] However, Seek uses a cut-down version of the AI which less reliable than the iNaturalist version (Jerry Cooper, pers. comm.).

4.2.3 Field guides, booklets, and invasive plant websites

Like the interactive keys and smartphone apps, the field guides, booklets and websites on invasive plants / weeds are also derived from the underpinning information in the technical databases and floras but repackaged to be user-friendly for non-experts. Many of the resources outlined in this section were developed by a few key people on modest budgets, who have had botanical names and other information checked by a relatively small pool of experts and colleagues, often on a voluntary basis.

An Illustrated Guide to Common Weeds of New Zealand (Popay et al. 2010) is the most useful contemporary field guide for recognising invasive plants in NZ. This book was first published in 1998 and has grown with each edition. It remains popular among plant pest managers and the general public for its comprehensive coverage, succinct descriptions, and excellent photographs.

Paralleling the decline in taxonomic expertise and resourcing to produce printed floras, the age of the NZ experts required to produce the common weeds book and the lack of recruitment to replace them is a major issue. The senior author of the common weeds book, Ian Popay, contributed to both this and the AgPest resource during his retirement, but recently passed away (September 2019). The remaining authors, Trevor James (AgResearch) and Paul Champion (NIWA), are senior career scientists who have worked on editions of this book during their personal time (and proceeds go to the NZ Plant Protection Society, not the authors).

The National Pest Plant Accord (NPPA) is available as a free booklet (MPI 2020) and online (www.biosecurity.govt.nz/protection-and-response/long-term-pest-management/national-pest-plant-accord). The NPPA was established in 2001 and is a cooperative agreement between MPI, NZPPI, DOC, and regional councils. Its purpose is to stop the spread of pest plants via the casual, nursery or retail trade, where distribution through these trades is the plants' primary distribution pathway. All plants on the NPPA list are unwanted organisms under the Biosecurity Act 1993.

Because of the submission and agreement process, there appears to be an uneven mix of species in the NPPA, ranging from those rare or absent from NZ (e.g. balloon vine, *Cardiospermum halicacabum*), to those widespread (fully naturalised) in the wild and unlikely to be cultivated (e.g. tussock hawkweed, *Hieracium lepidulum*). There are also invasive species that are common in cultivation but missing from the NPPA (see Appendix 1), few of which are of high value to the plant production industry (Malcolm Woolmore, pers. comm.).

Also, many species listed on the NPPA remain common and persist in public and especially private gardens (e.g. Japanese honeysuckle, *Lonicera japonica*). Botanic gardens have actively removed some NPPA species[8] but others remain.

[8] For example, phragmites (*Phragmites australis*) was removed from the Christchurch Botanic Gardens (Sue Molloy, pers. comm.).

Without a formal exemption issued by MPI (e.g. Auckland Botanic Gardens invasive plant collection, grown in a secure area for training purposes), NPPA species are prohibited from being exhibited under Section 53 (1) (a) of the Biosecurity Act 1993. This part of the legislation remains an issue for public gardens where NPPA species still grow and private gardens that are intermittently open to the public, as owners can potentially be prosecuted for displaying them.

The NPPA list has progressively grown with each review. The current accord lists 163 pest plant species banned from sale, distribution and propagation within NZ. There is potential to remove species that have probably been eliminated from NZ (e.g. bogbean, *Menyanthes trifoliata*) and that would remain unwanted organisms under the Biosecurity Act 1993.

Although the intent is to review the NPPA every 5 years, the last major review was held in 2012 and no species have been added since then. The current review of the Biosecurity Act, consideration of a 2016 report (Heenan & Champion 2016), and higher biosecurity priorities are factors in this delay (John Sanson and Kate Brown, pers. comm.).

A report prepared for MPI by Peter Heenan (Wildlands, now MWLR) and Paul Champion (NIWA) analysed the species composition in the NPPA. They plotted each species on an S-shaped invasion curve and demonstrated that the majority of species were widely established and well past the initial establishment phase. Many species on the NPPA that are widely established are likely to be predominantly dispersed by mechanisms other than deliberate human spread. Heenan and Champion (2016) have argued that for these species, the NPPA would have limited effectiveness at preventing future spread (Peter Heenan and Paul Champion, pers. comm.). This view is consistent with the role of the NPPA Steering Group, which needs to be satisfied that banning the trade of a plant would limit the spread of the species.

Notwithstanding some frustration over the lack of a current review, past reviews have demonstrated good cooperation between diverse parties of the Accord (Paul Champion, Peter Heenan, Malcolm Woolmore, pers. comm.).

A useful section of the MWLR website provides abundant information on the biocontrol of invasive species and the ecology of weeds. These pages provide information on research, biocontrol in NZ, education resources, videos and newsletters (www.landcareresearch.co.nz/science/plants-animals-fungi/plants/weeds/biocontrol). They are not profiled in Appendix 1.

Three websites profiled in Appendix 1 are dedicated to raising awareness of weeds in NZ: Weedbusters NZ, AgResearch's AgPest website, and the Massey University New Zealand Weeds Database (which is not a true database). Although they were developed for different reasons with different funding streams, they are useful resources that profile invasive plant species and offer practical advice on their control.

Weedbusters NZ has the strongest advocacy and outreach roles, with the widest range of resources (e.g. website, and printed handouts, including the popular Plant Me Instead booklets). This resource is currently the most vulnerable, with the National Coordinator role presently vacated.

Not profiled in Appendix 1 are two NZ websites created by commercial companies focused on the chemical control of invasive plants:

- Bayer Crop Science NZ weed pages (www.cropscience.bayer.co.nz/pests/weeds)
- Kiwicare® Problem Solver (www.kiwicare.co.nz).

Both feature the ability to select a weed species and then find the recommended method of chemical control.

4.2.4 Regional Pest Management Plans

Each regional council is responsible for and produces its own Regional Pest Management Plan (RPMP). This fractured approach risks a lack of coordination and having different names appearing for the same pest species, and there has been a push to get more coordination. Councils are required to comply with the National Policy Direction for Pest Management, which has led to consistency of programme names (categories of control) within each RPMP (exclusion, eradication, progressive containment, sustained control, site led), and to consult with their neighbouring council(s) during plan development. One or more councils are supposed to peer review each plan as part of the process. There is a Biosecurity Managers project collating information and lessons learnt from the latest round of pest plans as well, with one outcome being the intention to improve coordination of plan development in the future (Randall Milne, pers. comm.). RPMPs are reviewed every 5 years, with individual councils deciding on the effective term of each (up to 20 years).

Some councils have profiles of pest plant species on their websites. These compete to a certain extent with profiles on Weedbusters NZ. Although not perceived in this report as a major issue, it would be more efficient to treat Weedbusters NZ as the centralised source and invest in adding new invasive species profiles there.

MPI used to maintain an online database ('Biosecurity activity and performance data'), whereby users could find which species (plant and animal pests) were in which individual RPMP strategies and what their management statuses were. However, this was decommissioned a year or two ago due to using an outdated platform that was expensive to maintain and difficult to update (John Sanson, pers. comm.).

Bionet.nz, a collaboration between Biosecurity NZ, DOC, LINZ and regional councils for connecting pest information, usefully lists individual RPMPs as PDF links (www.bionet.nz/library/national-and-regional-plans-and-strategies/regional-pest-management-plans-or-strategies/). However, a modern database solution to connect the RPMP, NPPA and DOC Environmental Weeds resources at the regional (for RPMPs) and

taxon levels is currently lacking[9]. Pest plant managers and those working in the plant production industry would find a new combined resource such as this very useful.

Regional council pest plant (biosecurity) officers work with landowners to help manage invasive plants growing on their properties. They also enforce the NPPA, typically working with plant producers and retailers. Although there is healthy recruitment of younger staff, the role has changed over the years, and there is a relatively high turnover of these officers, consistent with current employment trends. Often by the time people are fully trained on the basics (over about a 2-year period) they leave to further their careers elsewhere. Because some do not see it as a long-term career, they don't acquire the knowledge and experience to become the next generation of team leaders/managers with a higher-level strategic view (Laurence Smith and Randall Milne, pers. comm.).

4.3 Outreach, citizen science and social media

4.3.1 Outreach

DOC, regional councils, Crown Research Institutes (CRIs), Weedbusters NZ and other organisations undertake outreach programmes to schools, whānau and community groups to raise public awareness of invasive plant issues.

Because DOC rangers work in the field and are involved in active weed control, they often engage with the public as effective advocates. DOC has an Outreach and Education team that coordinate and promote conservation initiatives, including those on invasive plants. DOC-led programmes have included the 'War on Weeds' (2015) and 'Dirty Dozen' (2017) initiatives launched during Maggie Barry's time as Conservation Minister. DOC has also been the principal funders of the Weedbusters NZ programme.

In addition to the roles of regional council pest plant (biosecurity) officers in enforcing the NPPA and RPMPs, education and outreach also play an important part. Biosecurity advisors work at a higher level with coordination roles in outreach, and regional council staff involved in environmental outreach are often also Enviroschools regional coordinators.

For the CRIs, outreach is usually achieved through short-term co-funded projects, or in conjunction with research programmes that have significant outreach/education components. Examples of CRI outreach on invasive plants are the MWLR 'Winning the War against Weeds' (2016) and 'The Great Weeds Hunt Aotearoa' (2018) in-school programmes. These NZ-wide projects were co-funded by the Curious Minds MBIE Participatory Science Platform, and partnered with botanists, biocontrol experts,

[9] It is achieved in part on the nzflora search page (www.nzflora.info/browse.html) by applying two 'Management Status' filters ('Environmental Weed' and/or 'Regional Pest'), and in the Key to weed species of New Zealand (www.landcareresearch.co.nz/resources/identification/plants/weeds-key) by selecting three choices under 'Other Information' (corresponding to RPMP, NPPA and DOC environmental weeds), but neither of these options drills down to species listed on individual RPMPs.

environmental educators, teachers, and community groups. They leveraged existing resources (many of which are profiled in this report), including MWLR classroom lessons on weeds and biocontrol, the online key to the weed species of NZ, iNaturalist NZ, the book *An Illustrated Guide to Common Weeds of New Zealand*, Weedbusters NZ handouts, and the NPPA booklet (see www.landcareresearch.co.nz/information-for/citizen-science/weeds/resources).

As well as classroom activities, smartphone apps ('Environmental Weeds of Australia' and iNaturalist) were used to identify and record invasive plants in the school grounds and nearby environment. The 'Winning the War against Weeds' and 'The Great Weeds Hunt Aotearoa' programmes engaged with 19 schools from four regions (2016 to 2019) and were used as NZ exemplars for an international review of best practices for education about invasive alien species from six countries (Verbrugge et al. in press).

Weedy outreach programmes such as these achieve increased awareness of invasive plants and biocontrol by schools and their communities, connect researchers to communities, and have potential for wider delivery. However, the MBIE Unlocking Curious Minds fund receives applications from all fields of science and technology, so it cannot be relied upon to provide continuity or expansion of invasive plant outreach. Even with significant co-funding, outreach programmes such as these are time-consuming and difficult to justify by CRIs in terms of research values alone.

4.3.1 Citizen science

There is no doubt that iNaturalist NZ – Mātaki Taiao is the premier citizen science platform for NZ. It is the NZ node of an international platform sharing observations of life (plants, fungi, insects, animals etc.). The iNaturalist platform delivers a wealth of features (e.g. browser and app interfaces, machine image and community identification, public comments and inbuilt messaging, project creation, distribution mapping, phenology recording, and data import/export).

A few examples of the range of resources on iNaturalist NZ relevant to invasive plants include:

- an NPPA checklist (https://inaturalist.nz/check_lists/176323-National-Pest-Plant-Accord-species)
- a 'Pest Plants (Weeds) of NZ' project (https://inaturalist.nz/projects/pest-plants-weeds-of-nz)
- an umbrella project grouping weeds observed by NZ schools as part of MWLR outreach (https://inaturalist.nz/projects/weeds-observed-by-new-zealand-schools).

The iNaturalist code bases are open source, allowing the creation/interface of related derivatives such application programming interfaces (APIs) and the previously mentioned 'QuestaGame' (a good example of 'gamification' of citizen science) and 'Find-A-Pest' apps. With this extensive functionality, there should be little need to create similar but disconnected resources, such as those on the Stop Wild Ginger – Patua te taru kino website (www.stopwildginger.co.nz), and arguably the Weedmanager app currently under development by Groundtruth (Daniel Bar-Even, pers. comm.).

Because iNaturalist NZ leverages multimillion-dollar development (centred in California) and has a large, voluntary contributor base, it provides many benefits for managing invasive plants at minimal cost. (In comparison, the New Zealand Bio-Recording Network has charitable status and a modest budget.) Borrowing from a concept advocated by MPI Biosecurity NZ of having 'A biosecurity team of 4.7 million' (now 5 million), iNaturalist NZ has more than 16,000 observers with the potential to discover new incursions of invasive species. A recent example is the detection through iNaturalist NZ of a species new to NZ, Himalayan wineberry (*Rubus ellipticus*)[10], listed as one of the world's 100 worst weeds (Global Invasive Species Database 2013). Through iNaturalist NZ, distribution range extensions for invasive plants are continually being uncovered (e.g. Sullivan et al. 2019). Scientific value is also added by 'Research Grade' data provided from iNaturalist to GBIF.

4.3.2 Social media

Useful advocacy for invasive plant management is provided by social media, and especially Facebook groups (not profiled in Appendix 1). A wide audience can be reached quickly and easily, ranging from invasive plant managers to restoration groups and the general public. Three NZ Facebook groups focusing on weeds are:

- Weeds in New Zealand (www.facebook.com/groups/Weeds.in.New.Zealand/): 'Anything to do with invasive plant species in New Zealand'
- Weeders for Conservation – New Zealand (www.facebook.com/groups/640252982787821/): 'For people who are passionate about protecting our native plant communities from invasive plants'
- Conservation Volunteers New Zealand (www.facebook.com/CVNewZealand): who help unemployed people get back into the workforce and have a professional website that includes videos of weed control (https://conservationvolunteers.co.nz/community-conservation-weed-control/).

These Facebook groups exchange information, provide practical advice on invasive plant control, organise control days of invasive plants and planting days of natives, and undertake the identification of weed images posted by the community.

Two useful Facebook groups focused on the identification of plants (invasive and non-invasive, indigenous and exotic) are:

- Plant Identification New Zealand (www.facebook.com/groups/317831921904857/): 'a group for identifying plants in Aotearoa'

[10] This species was first observed in New Zealand in August 2018 by Harshi Tharaka, and Stephen Thorpe was the first to correctly identify it (https://inaturalist.nz/observations/15185681). These details are lacking from the media releases made in July 2019. Formal identification and description of *Rubus ellipticus* var. *obcordatus* was published by de Lange et al. (2019).

- Plant Identification (www.facebook.com/groups/156706504394635/): an international plant identification service with strict guidelines aimed at fast and accurate identification and minimal conversation.

Facebook groups such as these undoubtedly provide useful engagement, outreach, and recruitment opportunities for invasive plant initiatives. However, identification requests for plant images posted only on social media undermine the value of uploading them on true citizen science platforms. Valuable information, such as new locations for invasive species, is being posted on Facebook but missing from iNaturalist NZ. Social media posts divide effort, have a short lifespan, reach fewer experts/researchers/scientists (for reliable identifications), lack data (such as localities), and do not provide a platform dedicated to data handling and exploration of biota. Other than providing encouragement to upload their images to citizen science platforms, little can be done about the personal choices of users.

5 Conclusions

As outlined in the Discussion and Appendix 1, there is a wide array of accessible resources to help manage and raise awareness of invasive plants in NZ. These range from online technical databases of names curated by CRIs (e.g. NZOR), to free public handouts and websites focused on invasive plants (e.g. the NPPA manual from MPI Biosecurity New Zealand and the Plant Me Instead booklets from Weedbusters NZ), and the outstanding iNaturalist citizen science platform. MWLR hosts a wealth of relevant resources, including plant names databases, e-floras, interactive keys, biocontrol information, and outreach resources.

5.1 Management of plant names

Using up-to-date and currently accepted botanical names is essential for invasive plant management. Different names, such as synonyms and imprecise common names instead of a currently accepted name, create confusion and introduce errors.

Primary resources for managing scientific names in NZ are the PND (for botanical names) and NZOR (for all biota). Both were developed by MWLR, who are leaders in creating accessible, well-structured, and interconnected names databases. The PND is continually updated by professional botanists at the Allan Herbarium, based on taxonomic treatments in NZ and worldwide[11].

[11] Resources that use invasive species names in a secondary sense, and have used MWLR's expertise and names databases as a primary resource to achieve concordance at the time of publication, include the online key to weed species of New Zealand, Weedbusters NZ, *An Illustrated Guide to Common Weeds of New Zealand*, and the NPPA.

Plants invasive to NZ are *exotics*: non-indigenous species introduced from other countries[12]. The naturalised and cultivated-only exotic species in NZ far outnumber the indigenous flora. This presents a challenge to keep up with overseas literature to align taxonomic name changes. A possible solution to streamline this process may be to interface the MWLR plant names databases with international databases.

The Biosecurity New Zealand PBI is currently the main online source of names of exotic plant species considered to be present ('not new') in NZ. Although the PBI fulfils its purpose of managing biosecurity requirements of plant material, it appears to be failing to accurately maintain an up-to-date and accurate list of species deemed 'new' and 'not new' organisms under the HSNO Act 1996, and its taxonomic name handling is not fit for purpose. Some of the names weaknesses (e.g. limited synonyms, no author authorities or references) make it difficult to validate species names, identities, and presence in NZ. These name-handling weaknesses in the MPI systems extend to the Biosecurity New Zealand UOR databases, with no interconnections between the PBI and UOR and no external names feed.

NZOR was designed from the outset to provide the database infrastructure for interconnecting and exchanging plant names data with other parties. The opportunity for and advantages of connecting these resources is obvious: NZOR could provide the name-handling functions, backed by botanical experts and the research community, and MPI could associate these more rigorously curated names with their various regulatory standards and biosecurity needs. Access to up-to-date and better curated names within MPI could also allow for more efficient updates of their other resources, such as names used in the NPPA. This idea is not new: for more than a decade it has been seen as a desirable outcome by individuals from several organisations. It is technically achievable but lacks a high-level MOU between MPI and MWLR, funding commitments, and action plans.

Unfortunately, the flow of species names from the EPA, as a result of their presence in New Zealand (Section 26) determinations of the HSNO Act 1996, to any uptake in the MPI Biosecurity New Zealand PBI is also somewhat disconnected and not guaranteed. MPI are likely to prioritise commercially significant species and to develop import health standards for these, leaving an increasing number of species missing from the PBI.

To help address this significant data gap (reported 10 years ago by Dawson 2010), from January 2020 MPI's Sustainable Food & Fibre Futures fund is supporting a new 3-year project 'Taking Stock: Resolving New Zealand's Cultivated Plants Problem', with co-funding provided by the Royal New Zealand Institute of Horticulture (RNZIH), other horticultural organisations, and MWLR. Many thousands of plant names will be accumulated, resolved, and added to the PND and NZOR. In addition, best evidence cases will be submitted to the EPA for Section 26 determinations. The large scale of the problem of missing plant names for cultivated species on 'official' NZ databases means that while

[12] Indigenous species can sometimes be considered invasive within New Zealand, where they vigorously colonise outside of their natural distributions.

significant progress is expected to be achieved, the project is unlikely to resolve all names within the relatively short 3-year time frame.

5.2 Overlapping and duplicated resources

The 'Discussion' and Appendix 1 comment on many more-or-less overlapping and duplicated resources for managing invasive plants, due to their history of development and funding sources.

The most notable overlaps/duplications are the various online weed profiles (e.g. AgResearch, Massey University, MWLR, Weedbusters NZ, and on regional council websites), and also species descriptions (MWLR and NZPCN). Future work on these should consider (if practicable) integration of these weed profiles or contributing to a centralised resource.

An area of duplication that has negative impacts for efficient management of invasive plant is the independent development of smartphone apps to record invasive species that do not contribute data to iNaturalist or GBIF.

5.3 Missing resources

The most significant missing resource[13] identified in this report is the lack of a comprehensive invasive plant database that provides a single location from which to retrieve information on multiple categories of invasive plants (and potentially animals). There include DOC environmental weeds, regional council RPMP species (collectively and by region), and NPPA species. GRIIS New Zealand invasive plants and MPI unwanted organisms could also be added.

Another gap is the lack of a LucidMobile smartphone app for the identification of invasive plants of NZ. Australia has the 'Environmental Weeds of Australia' app, but the equivalent NZ resource, the MWLR online key to weed species of NZ, is limited to a browser version that it not portable for field identifications.

5.4 Funding environment

There are several broader issues around funding and lack of agility for managing invasive species. These are important to mention but fall outside of the scope of this report to make them key issues with associated recommendations.

Many of the invasive plant resources outlined here (e.g. interactive key to the weed species of NZ, MWLR e-flora, and NZ Plant Conservation Network resources) would not exist without Terrestrial & Freshwater Biodiversity Information System (TFBIS) Programme funding support. This was a highly successful programme that did not have complications of co-funding or commercialisation requirements. The great majority of resources

[13] Connecting NZOR with MPIs plants management databases is not a missing resource: it is a lack of integration.

developed through TFBIS remain useful and available today. Unfortunately, TFBIS effectively ceased in 2015[14]; this was a major blow to biodiversity and digitisation funding, and nothing equivalent has taken its place.

Following the establishment of CRIs (corporatised Crown entities) in 1992, tasked with scientific research, there has been a progressive shift from ongoing, underpinning 'public good' research towards short-term, highly contestable, high-profile 'new' or 'stretchy' projects. It is difficult to achieve continuity of research within this framework.

The Strategic Science Investment Fund (SSIF), managed by MBIE, funds 'strategic investment in research programmes and scientific infrastructure that have long-term beneficial impact on New Zealand's health, economy, environment and society.' Rebidding SSIF programmes every 5 years and having Endeavour programmes 3–6 years duration is arguably not long term research from an ecological and systematics perspective, is time-consuming for scientists (which reduces their effective research time), and is of dubious benefit for ongoing 'core' SSIF work such as Nationally Significant Databases and Collections (NSDCs).

The recent (2020) announcement that the NZ Government will provide a one-off, 2-year increase in CRI funding for SSIF platforms of $19.5 million per year, and for the NSDCs, is encouraging as NSDC funding has remained static for many years. Also positive is government investment into research and control of wilding conifers from 2016.

In the current funding environment there are minimal discretionary hours for outputs and collaborations that are not part of current research programmes or subcontracts. For example, because it is not a research-related output, editions of the common weeds of NZ book have been edited during AgResearch, NIWA and MWLR researchers' own time in the evenings and weekends. This is not an unusual scenario for researchers.

5.5 Lack of agility and legislative issues

NZ's responses for managing invasive plants are far from agile. Rapid detection of newly invasive species, followed by immediate and hands-on management strategies, has the best and most cost-effective outcomes to beat the exponential part of an invasion curve and may even achieve eradication (Figure 1). It is sobering to note that the recent wilding conifer management programmes (Wyatt 2018) were established more than 40 years after ecologists were aware of the emerging threat. RPMPs are reviewed every 5 years, with terms of up to 20 years, and the NPPA has not been renewed for 8 years[15].

[14] This programme was established to 'Support seamless access to essential biodiversity data, information and knowledge to achieve the goals of the New Zealand Biodiversity Strategy 2000'. The website at www.doc.govt.nz/get-involved/funding/tfbis-biodiversity-information-fund/ states, 'There is currently no Terrestrial and Freshwater Biodiversity Information System (TFBIS) funding round', but does not state that the funding programme has ceased.

[15] MPI have scheduled a full review of the NPPA for 2021 (Kate Brown, pers. comm.).

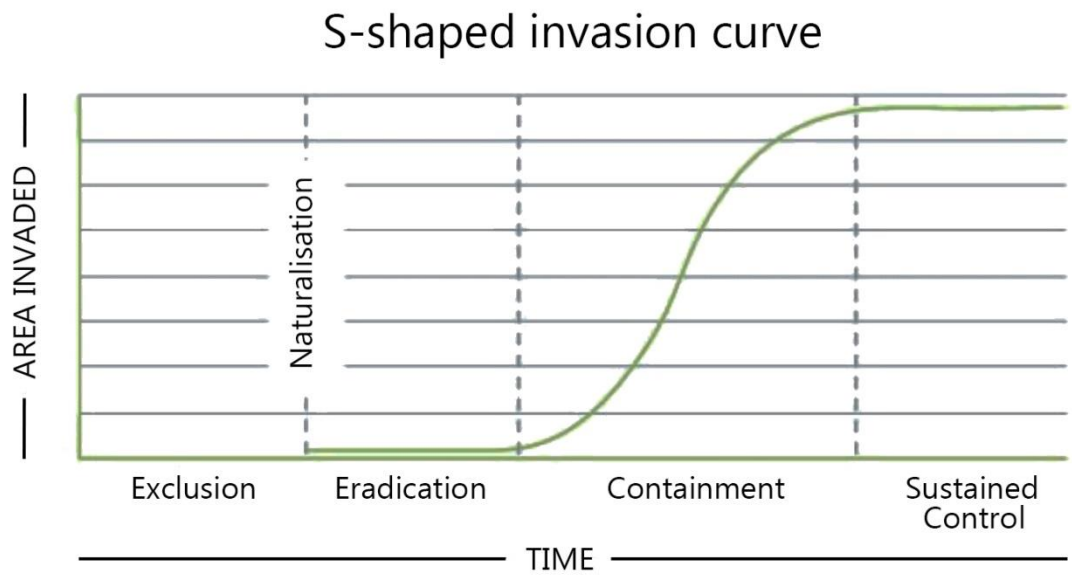

Figure 1 Invasion curve (adapted from Bourdôt et al. 2018).

Species tend to be noticed only after they have become a major problem, meaning that new but obviously invasive species can be missed from successive RPMPs and NPPA's. As a consequence, they are also excluded from regional councils' control and funding priorities. For example, *Lomatia fraseri* (a shrub / small tree in the Proteaceae family and native to eastern Australia) was recently discovered invading ridges near Wainuiomata, where there are thousands of plants (Perrie 2019), but the species is missing from the finalised 2019–2039 Greater Wellington Regional Council RPMP. This means that control is not prioritised under their management plan, and it's difficult to alter an existing RPMP if there are impacts to any changes made (e.g. public consultation and access to privately owned land). *Lomatia fraseri* has probably spread from cultivation, and it is not listed on the current NPPA either.

Because each regional council is responsible for invasive species management within their own territory there can be a lack of coordination and little umbrella funding. A National Weeds Distribution Database was proposed 10 years ago (Cooper et al. 2010), to better support regional decision making and management of weeds, but failed to gain funding. The *status quo* persists, whereby each regional council manually maintains a separate list of invasive species. Failure to consult NZOR and the PND as primary resources may result in divergence of names used in RPMPs for invasive species.

The Biosecurity Act and HSNO legislation use a species-based regulatory approach. This works reasonably well for animals, but has difficulties when applied to plants. Plants are more variable, with cryptic species, extensive hybridisation, and weedy and non-weedy subspecies, varieties and genotypes. A trait based approach would identify taxa that are known to be invasive in other countries and those that have potential to become invasive in NZ. A taxon approach, not limited to the species level, would help identify, for example, non-invasive genera, or a single invasive subspecies. Both approaches may make better biological sense in terms of import decisions and managing invasive species, but legislative changes, including the current review of the Biosecurity Act, are outside of the scope of this report.

6 Recommendations

Based on the existing resources profiled in this report, and after examining the gaps and opportunities, the following recommendations are made to more effectively manage invasive plants in NZ.

- Encourage recognition of MWLR and its collaborators as the primary providers of scientific names for NZ, through the PND (for botanical names and invasive plants) and the NZOR (for all biota), and advocate for adequate and ongoing funding of these resources.
- Seek high-level agreement between relevant organisations and an action plan to connect NZOR's name management infrastructure to MPI's (and ideally the EPA's) regulatory and unwanted species resources in order to efficiently handle the scientific names used by those organisations, including the PBI and UOR.
- Create a database-driven solution to integrate and deliver under the same resource clearly defined categories of invasive plants, including DOC environmental weeds, regional council RPMP species, and NPPA species.

A number of broader issues were raised during this project but fall outside the scope of this report in terms of making recommendations.

- Funding models for CRIs demonstrate a progressive shift towards short-term, highly contestable, high-profile, 'new' or 'stretchy' projects. This shift has an impact on the capacity to conduct ongoing, underpinning research on invasive plants.
- The legislative framework is not as agile as it could be, especially for MPI and regional councils, which need to undertake rapid detection of newly invasive species and devise control/elimination strategies that are cost-effective by beating the species' invasion curves.
- The Biosecurity Act and HSNO legislation use a species-based regulatory approach rather than a trait (weediness) and taxon (not limited to the species level) approach, which may make better biological sense in terms of managing invasive species.

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8 Glossary

Adventive species: a species (e.g. plant, animal) that is not **indigenous** and has arrived in a new locality. It may have been humans assisted as an **introduced** species or it may not.

Biostatus: information to indicate the origins and occurrence of species in New Zealand. Biostatus terms, as used by MWLR, are explained at: https://nzflora.landcareresearch.co.nz/WebForms/DisplayForm_biostatus_NZFlora.aspx and https://plant-synz.landcareresearch.co.nz/database/biostatus.asp.

Character: botanically, the numerous features that are studied by taxonomists; for example, plant height, leaf width, flower colour (cf. **character states**).

Character states: different expressions of a given botanical character. It is important to distinguish between **characters** (features) and character states (the expression of those features). For example, plant height, leaf width and flower colour are characters, whereas plants 2 m tall, leaves 10 mm wide and flowers yellow are character states.

Cultivated: as defined by MWLR **biostatus**, plants that exist only in cultivation in New Zealand.

Driver weeds: weeds that drive a grower's weed management plan and decisions. Driver weeds can destroy a crop, add a significant number of seeds to the seed bank and force growers to rotate to other crops. Although this term is well established in other countries, it is not commonly used in New Zealand. A good example for New Zealand is the 2015–2016 seed line of imported fodder beet contaminated with velvetleaf (*Abutilon theophrasti*) (cf. **passenger weeds**).

Endemic: having a natural distribution restricted to a particular geographical region. New Zealand has c. 80% endemic (higher) plant species not found naturally in any other country. The eflora (www.nzflora.info/browse.html) currently lists 1,884 species endemic to New Zealand (cf. **indigenous/native**).

Environmental weeds: plants that invade natural ecosystems and are considered to be a serious threat to those ecosystems. Australia and New Zealand, where biota with a high degree of endemism have evolved, are particularly susceptible to environmental weeds. For New Zealand, Howell (2008) lists 328 environmental weeds targeted for management on the Department of Conservation estate.

Exotic: not native; introduced from another region or country. For New Zealand plants, the term usually means **introduced** from overseas. The eflora (www.nzflora.info/browse.html) currently lists 2,841 exotic plant species present in New Zealand, but the true total is unknown, with estimates ranging from 25,000 to 50,000 taxa.

Indigenous/native: naturally occurring in the area but not necessarily confined to it. The eflora (www.nzflora.info/browse.html) currently lists 654 plant species indigenous (but non-endemic) to New Zealand (cf. **endemic**).

Introduced: a plant that does not occur naturally in the area where it is growing; alien, **exotic**. For New Zealand plants, the term usually means introduced from overseas.

Invasive alien species (IAS): defined by the International Union for Conservation of Nature (IUCN) as 'plants or animals that are introduced by [human activity], accidentally or intentionally, outside of their natural geographic range into an area where they are not naturally present. They are often introduced as a result of the globalisation of economies, for instance by trade via ships, shipment of wood products infested with insects, or the transport of ornamental plants that then establish themselves into the wild and spread … Invasive alien species (IAS) can have very severe effects on new environments. Many alien species become invasive, competing against or preying on native species, which can lead to their extinction and eventual ecological devastation.' (www.iucn.org/regions/europe/our-work/species/invasive-alien-species).

Invasive plants: plants that are not native to a specific location, and have an ability to spread to a degree believed to cause damage to the environment, human economy or human health. The term, as most often used, applies to **introduced** plant species that adversely affect the habitats and bioregions they invade economically, environmentally, or ecologically.

Naturalised: an introduced plant now freely reproducing in well-established populations. They may also be called **exotic**, **introduced**, adventive, or alien species. They may have either arrived accidentally or been deliberately introduced. This group includes plants that have escaped from cultivation and have established breeding populations in the wild.

Passenger weeds: weeds that become abundant with the decline of native plant communities. Although this term is well established in other countries, it is not commonly used in New Zealand (cf. **driver weeds**).

Pest plants: 'pest plants' (and pest animals) as used by New Zealand agencies (such as the Ministry for Primary Industries and regional councils) has the same meaning as

in the Biosecurity Act 1993: 'an organism specified as a pest in a pest management strategy.'

Species (abbrev. sp. singular; spp. plural): the fundamental unit of study in taxonomy, comprising all the populations of one breeding group that are normally permanently separated from other such groups by marked discontinuities.

Synonym (taxonomic): in scientific nomenclature, a synonym is a scientific name that applies to a **taxon** accepted under a different scientific name. For any given taxon, only one scientific name is considered to be the correct one, and is determined by applying the relevant code of nomenclature.

Systematics: the scientific study and description of the variation of living organisms, and the relationships that exist between them (the term is often used interchangeably with **taxonomy**, but strictly speaking, taxonomy is a specialist field within systematics).

Taxon (plural taxa): a named taxonomic group at any rank (e.g. family, genus, species, subspecies). For example, at the family level, taxa may be represented by the Convolvulaceae and Fabaceae, while *Convolvulus* and *Ulex* are examples of genus-level taxa.

Taxonomy: the study of the principles and practices of classification; the establishing and defining of relationships. The term is often used interchangeably with **systematics**, but taxonomy is strictly only part of systematics.

Transformer/transformational weeds: an invasive plant species that has the capacity to transform the character, condition, form or nature of one or more ecosystems over substantial areas relative to the extent of that ecosystem. Transformer weeds can out-compete other plants to form monocultures. They have the capacity to undermine the ecological processes that maintain the health of native vegetation and hence the habitat of indigenous plants and animals. For New Zealand, transformer weeds include broom (*Cytisus scoparius*), gorse (*Ulex europaeus*), needlegrass (*Nassella* spp.), and contorta pine (*Pinus contorta*).

Weed: any plant growing well where it is not wanted. Weeds typically have high seed production and an ability to colonise disturbed ground quickly. Most New Zealand weeds are exotic species, accidentally or deliberately introduced by people. Introduced species may be useful in some contexts but weedy elsewhere. For example, red and white clover (*Trifolium pratense* and *T. repens*) are valuable pasture plants but can be **invasive** in horticultural crops.

Several New Zealand indigenous species are also considered weeds when growing where they are not wanted. For example, native mānuka (*Leptospermum scoparum*) is valued for its honey, medicinal properties and firewood, but can also be considered a scrubby weed of poorer pastures. Pōhutukawa (*Metrosideros excelsa*) is another example of an indigenous species considered invasive when spreading outside its natural range.

There are many classifications of weeds, including agricultural weeds, common (garden) weeds, **driver weeds**, economic weeds, **environmental weeds**, horticultural weeds, **passenger weeds**, pastoral weeds, and **transformer/transformational weeds**.

9 Abbreviations

AgResearch[16]: a New Zealand Crown Research Institute serving the agriculture and biotechnology sectors of New Zealand industry. AgResearch was formerly known as New Zealand Pastoral Agriculture Research Institute Ltd.

APC: Australian Plant Census, an online database of the accepted scientific names for the Australian vascular flora.

AVH: Australasian Virtual Herbarium, an online resource that allows access to more than 8 million plant specimen records held by various Australian and New Zealand herbaria. It is part of the Atlas of Living Australia, and was formed by the amalgamation of Australia's Virtual Herbarium and the New Zealand Virtual Herbarium.

CHR: the internationally recognised (Index Herbariorum) acronym for the MWLR Allan Herbarium at Lincoln, New Zealand.

CRIs: Crown Research Institutes: corporatised Crown entities that conduct scientific research. Most New Zealand CRIs were established immediately following the Crown Research Institutes Act 1992, and dissolution of the Department of Scientific and Industrial Research and elements of other government departments.

DOC: Department of Conservation – Te Papa Atawhai, a public service department of New Zealand tasked with the conservation of New Zealand's natural and historical heritage.

EPA: Environmental Protection Authority – Te Mana Rauhī Taiao, a public service department of New Zealand with environmental regulation responsibilities. Established following the Environmental Protection Authority Act 2011, it is a successor to the Environmental Risk Management Authority.

GBIF: Global Biodiversity Information Facility, an international organisation that focuses on making scientific data on biodiversity freely available using web services. The data are provided by many institutions from around the world, and GBIF's information architecture makes these data accessible and searchable through a

[16] AgResearch is not an abbreviation, but included here among the explanations of organisations that do have acronyms.

single portal. Data available through the GBIF portal are primarily distribution data on plants, animals, fungi, and microbes for the world, and scientific names data.

GRIIS: Global Register of Introduced and Invasive Species, annotated and verified country-wise inventories of introduced and invasive species, contributing to a global register, a concept developed by the IUCN SSC Invasive Species Specialist Group (ISSG). Published GRIIS checklists can be downloaded from www.gbif.org/publisher/cdef28b1-db4e-4c58-aa71-3c5238c2d0b5, including a 2019 dataset for New Zealand (Champion et al. 2019) that lists 581 invasive plant species out of a total of 942 invasive species (plants, animals, fungi, chromists).

HSNO: Hazardous Substances and New Organisms, refers to the HSNO Act 1996, an Act aiming to protect the environment, and the health and safety of people and communities, by preventing or managing the adverse effects of hazardous substances and new organisms. Related legislation is the Biosecurity Act 1993.

IAS: invasive alien species (see Glossary for definition).

IPNI: International Plant Names Index, a database of the names and bibliographical details of seed plants, ferns and lycophytes.

LINZ: Land Information New Zealand – Toitū Te Whenua, the public service department of New Zealand tasked with geographical information and surveying functions, as well as handling land titles and managing Crown land and property.

MBIE: Ministry of Business, Innovation and Employment – Hīkina Whakatutuki, the public service department of New Zealand tasked with 'delivering policy, services, advice and regulation' that contribute to New Zealand's economic productivity and business growth.

MfE: Ministry for the Environment – Manatū Mō Te Taiao, a public service department of New Zealand tasked with advising the government on policies and issues affecting the environment, in addition to the relevant environmental laws and standards. The Environment Act 1986 is the foundation law establishing the Ministry.

MPI: Ministry for Primary Industries – Manatū Ahu Matua, the public service department of New Zealand tasked with overseeing, managing and regulating the farming, fishing, food, animal welfare, biosecurity, and forestry sectors of New Zealand's primary industries. It was formerly the Ministry of Agriculture and Forestry (MAF). Biosecurity New Zealand is the division of MPI most relevant to this report.

MWLR: Manaaki Whenua – Landcare Research, a Crown Research Institute focused on environmental, biodiversity, and sustainability research in New Zealand. It maintains several collections of organisms that are of nationally significant importance to New Zealand.

NGO: non-governmental organisation: NGOs are organisations that are independent of any government and are usually non-profit.

NIWA: National Institute of Water and Atmospheric Research – Taihoro Nukurangi, a New Zealand Crown Research Institute conducting freshwater, marine, and atmospheric research.

NPPA: National Pest Plant Accord, a cooperative agreement between Biosecurity New Zealand, the Department of Conservation, New Zealand Plant Producers Incorporated and regional councils to prohibit a defined set of invasive species from sale, distribution and propagation within New Zealand. All plants on the Accord list are classed as unwanted organisms under the Biosecurity Act 1993.

NSDC: Nationally Significant Databases and Collections, 25 datasets and collections registered as important for New Zealand and supported by long-term government funding. A recent review report and terms of reference are available on the MBIE website.

NVS: New Zealand National Vegetation Survey Databank, New Zealand's repository for ecological data on vegetation structure and composition, and also a nationally significant collection and database. It is maintained by Manaaki Whenua – Landcare Research.

NZBRN: New Zealand Biodiversity Recording Network, a charitable trust which aims to increase New Zealanders' engagement with and knowledge of nature. Their main activities centre on iNaturalist NZ – Mātaki Taiao (formerly NatureWatch NZ), a free, online web platform for exploring and recording New Zealand (and world) biodiversity.

NZOR: New Zealand Organisms Register, a comprehensive online catalogue of taxonomic names of New Zealand biota (and other taxa of importance to New Zealand). NZOR has two components: the network of data providers and the information infrastructure to collate and deliver data to end-users. It is headed by a multi-agency Steering Group established in 2006.

NZPCN: New Zealand Plant Conservation Network – Rōpū hononga Koiora Taiao ki Aotearoa, a non-governmental organisation focused on protecting and restoring New Zealand's indigenous plant life, including vascular plants, mosses, liverworts, hornworts and lichens.

NZPPI: New Zealand Plant Producers Incorporated, the advocacy and industry body for New Zealand plant producers and associated industry; formerly the Nursery & Garden Industry Association.

NZPPS: New Zealand Plant Protection Society (Inc), an organisation that aims to share knowledge on the management of weeds, pests and pathogens of plants in New Zealand.

PBI: Plants Biosecurity Index, an online database, maintained by MPI Biosecurity New Zealand, of plant species that have requirements that must be met under the HSNO Act 1996 before plant material can be imported into New Zealand.

PCE: Parliamentary Commissioner for the Environment – Te Kaitiaki Taiao a Te Whare Pāremata, an independent Officer of the New Zealand Parliament appointed by the Governor-General on the recommendation of the House of Representatives for a 5-year term under the Environment Act 1986.

PND: an informal abbreviation for Ngā Tipu o Aotearoa – New Zealand Plants names database. This database manages and delivers referenced, scientific and common names of the New Zealand flora.

RPMP: Regional Pest Management Plan, defined in the Biosecurity Act 1993 as 'a plan, made under Part 5 of this Act, for the management or eradication of a particular pest or pests'. RPMPs are reviewed every 5 years by each New Zealand regional council, and they outline programmes and priorities for managing plant and animal pest species in each region. Pest management programmes include exclusion, eradication, progressive containment, and sustained control. Formerly called Regional Pest Management Strategy (RPMS). RPMPs are listed at Bionet.NZ.

SCD: Systematics Collections Data, the specimen and culture database for nationally significant collections curated by Manaaki Whenua – Landcare Research: Allan Herbarium (CHR), International Collection of Microorganisms (ICMP), National New Zealand Flax Collection (FLAX), New Zealand Arthropod Collection (NZAC), and New Zealand Fungarium – Te Kohinga Hekaheka o Aotearoa (PDD).

SSIF: Strategic Science Investment Fund, managed by the Ministry of Business, Innovation and Employment to provide funds for strategic investment in research programmes and scientific infrastructure that have long-term beneficial impact on New Zealand's health, economy, environment and society.

TDWG: Taxonomic Databases Working Group, an international non-profit organisation and community dedicated to developing biodiversity information standards.

Te Papa: Museum of New Zealand Te Papa Tongarewa, New Zealand's national museum, located in Wellington.

TFBIS: Terrestrial and Freshwater Biodiversity System, a funding programme that ran from c. 2003 to 2015, administered by the Department of Conservation to 'Support seamless access to essential biodiversity data, information and knowledge to achieve the goals of the New Zealand Biodiversity Strategy 2000'.

TPL: The Plant List, a list of botanical names of plant species created by the Royal Botanic Gardens, Kew, and the Missouri Botanical Garden and launched in 2010. It was intended to be a comprehensive record of all known names of plant species, but has largely been superseded by World Flora Online.

UOR: Unwanted Organisms Register, a searchable register/database maintained by Biosecurity NZ of organisms capable or potentially capable of causing unwanted harm to any natural and physical resources or human health.

Weedbusters NZ: Weedbusters New Zealand, an advocacy and outreach resource to encourage communities to work together for the active control of weeds, and to promote education about invasive plants.

WFO: World Flora Online, an internet based compendium of the world's plant species, launched as a follow-up project to The Plant List.

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10.2 Websites and smartphone apps

10.2.1 New Zealand

AgResearch: AgPest: https://agpest.co.nz/

Bionet.NZ: Plant pests: https://www.bionet.nz/control/pests-under-management-2/

Bionet.NZ: Regional pest management plans or strategies: https://www.bionet.nz/library/national-and-regional-plans-and-strategies/regional-pest-management-plans-or-strategies/

Department of Conservation: Weeds: https://www.doc.govt.nz/nature/pests-and-threats/weeds/

Facebook: iNaturalist NZ – Mātaki Taiao: https://www.facebook.com/inaturalistnz/

Facebook: Plant Identification New Zealand: https://www.facebook.com/groups/317831921904857/

Facebook: Weeders for Conservation – New Zealand: https://www.facebook.com/groups/640252982787821/

Facebook: Weeds in New Zealand: https://www.facebook.com/groups/Weeds.in.New.Zealand/

Forest Protection_Scion: Find-A-Pest: Google Play: https://play.google.com/store/apps/details?id=scion.bss.android&hl=en_US Apple App Store: https://apps.apple.com/nz/app/find-a-pest/id1437330658

iNaturalist NZ – Mātaki Taiao: https://inaturalist.nz/

LucidMobile: NZ Coprosma Key: Google Play: https://play.google.com/store/apps/details?id=com.lucidcentral.mobile.coprosma Apple App Store: https://apps.apple.com/nz/app/nz-coprosma-key/id953914847

LucidMobile: NZ Orchid Key: Google Play: https://play.google.com/store/apps/details?id=com.lucidcentral.mobile.nz_orchid Apple App Store: https://apps.apple.com/us/app/nz-orchid-key/id1063192594

LucidMobile: NZ Wilding Conifers (Early Access): Google Play: https://play.google.com/store/apps/details?id=com.lucidcentral.mobile.nz_wilding_conifers

Manaaki Whenua – Landcare Research: Ngā Tipu o Aotearoa – New Zealand Plants database: https://nzflora.landcareresearch.co.nz/

Manaaki Whenua – Landcare Research: Resources: Identification: Plants: Key to Cotoneaster Species Present in New Zealand:

https://www.landcareresearch.co.nz/resources/identification/plants/cotoneaster-key

Manaaki Whenua – Landcare Research: Resources: Identification: Plants: Key to Flowering Plant Genera of New Zealand: https://www.landcareresearch.co.nz/resources/identification/plants/flowering-plants-key

Manaaki Whenua – Landcare Research: Resources: Identification: Plants: Key to the Weed Species of New Zealand: https://www.landcareresearch.co.nz/resources/identification/plants/weeds-key

Manaaki Whenua – Landcare Research: Resources: Identification: Plants: Key to Willow Species and Hybrids Present in New Zealand: https://www.landcareresearch.co.nz/resources/identification/plants/salix-key

Manaaki Whenua – Landcare Research: Resources: Identification: Plants: NZ Grass Key – Key to the Grasses of New Zealand: https://www.landcareresearch.co.nz/resources/identification/plants/grass-key

Manaaki Whenua – Landcare Research: Systematics Collections Data (SCD): Allan Herbarium (CHR) specimen database: https://scd.landcareresearch.co.nz/

Manaaki Whenua – Landcare Research: The Great Weeds Hunt Aotearoa: http://www.landcareresearch.co.nz/information-for/citizen-science/weeds

Manaaki Whenua – Landcare Research: Weedy Lessons and Activities: http://www.landcareresearch.co.nz/information-for/citizen-science/weeds/resources/weedy-lessons-and-activities

Manaaki Whenua – Landcare Research, Te Papa, and NIWA: Flora of New Zealand Online: Management Status filters: Regional Pest, Environmental Weed, Unwanted Organism: http://www.nzflora.info/browse.html

Massey University: New Zealand Weeds: https://www.massey.ac.nz/massey/learning/colleges/college-of-sciences/clinics-and-services/weeds-database/weeds-database_home.cfm

Ministry for Primary Industries: National Pest Plant Accord (NPPA): https://www.mpi.govt.nz/protection-and-response/long-term-pest-management/national-pest-plant-accord/

Ministry for Primary Industries: Plants Biosecurity Index (PBI): https://www1.maf.govt.nz/cgi-bin/bioindex/bioindex.pl

New Zealand Organisms Register (NZOR): http://www.nzor.org.nz/

New Zealand Plant Conservation Network: Exotic Plant Search Results: http://nzpcn.org.nz/

New Zealand Plant Producers Incorporated: National Pest Plant Accord (NPPA): https://nzppi.co.nz/advocacy/107-460/national-pest-plant-accord-nppa

New Zealand Plant Protection Society (NZPPS): https://nzpps.org/

Stop Wild Ginger – Patua te taru kino: http://www.stopwildginger.co.nz/

Weedbusters: https://www.weedbusters.org.nz/

10.2.2 International

Australian Plant Census (APC): https://www.anbg.gov.au/chah/apc/

Australasian Virtual Herbarium (AVH): http://avh.chah.org.au/

Facebook: Plant Identification: https://www.facebook.com/groups/156706504394635/

Global Biodiversity Information Facility (GBIF): https://www.gbif.org/

Global Compendium of Weeds (GCW): http://www.hear.org/gcw/

Global Invasive Species Database (GISD): http://www.iucngisd.org/gisd/

Global Register of Introduced and Invasive Species – New Zealand checklist.

iNaturalist: Google Play:
https://play.google.com/store/apps/details?id=org.inaturalist.android
Apple App Store: https://itunes.apple.com/nz/app/inaturalist/id421397028

International Plant Names Index (IPNI): https://www.ipni.org/

LucidMobile: Environmental Weeds of Australia: Google Play:
https://play.google.com/store/apps/details?id=org.lucidcentral.mobile.ewa

LucidMobile: Federal Noxious Weeds Key: Google Play:
https://play.google.com/store/apps/details?id=com.lucidcentral.mobile.fnw_tool

LucidMobile: Weeds of Australian Cotton: Google Play:
https://play.google.com/store/apps/details?id=com.lucidcentral.mobile.cotton_weeds

LucidMobile: Weeds of South East QLD and Northern NSW: Google Play:
https://play.google.com/store/apps/details?id=com.lucidcentral.mobile.sew_full

PlantNet Plant Identification: Google Play:
https://play.google.com/store/apps/details?id=org.plantnet

PlantSnap – Plants, Trees and Flowers Identifier: Google Play:
https://play.google.com/store/apps/details?id=com.fws.plantsnap2

Plants of the World Online (POWO): Kew Science: http://plantsoftheworldonline.org/

QuestaGame: Google Play:
https://play.google.com/store/apps/details?id=com.mobisys.biod.questabird
Apple App Store: https://itunes.apple.com/au/app/questabird/id886141835

Seek by iNaturalist: Google Play:
https://play.google.com/store/apps/details?id=org.inaturalist.seek
Apple App Store: https://apps.apple.com/us/app/seek-by-inaturalist/id1353224144

The Plant List (TPL): a working list of all plant species: http://www.theplantlist.org/

Wikipedia: Invasive species: https://en.wikipedia.org/wiki/Invasive_species

World Flora Online (WFO): a Project of the World Flora Online Consortium: http://www.worldfloraonline.org/

Appendix 1 – Invasive plant databases and associated resources

This appendix provides summary tables of major New Zealand resources that relate to invasive plants and explains any broader context of those resources. The summary tables comprise the following.

Technical databases and data stores:

- MWLR: New Zealand Organisms Register (NZOR)
- MWLR: Ngā Tipu o Aotearoa – New Zealand Plants names database (PND)
- MWLR: Systematics Collections Data (SCD): Allan Herbarium, and referencing other New Zealand herbaria and the Australasian Virtual Herbarium
- MWLR: New Zealand National Vegetation Survey (NVS) Databank
- MWLR: Datastore: NZ Non-native Flora Traits & Distributions
- MPI: Biosecurity New Zealand: Plants Biosecurity Index (PBI)
- MPI: Biosecurity New Zealand: Unwanted Organisms database (UOR).

E-floras:

- MWLR: Flora of New Zealand Online (nzflora), and referencing the printed floras
- NZPCN: exotic plant species profiles and related resources.

Interactive keys:

- MWLR: online key to the weed species of New Zealand, and referencing other Lucid keys that identify weeds.

Field guides, booklets, and invasive plant websites:

- NZPPS: *An Illustrated Guide to Common Weeds of New Zealand,* book, and referencing related books on New Zealand invasive plants
- MPI: Biosecurity New Zealand: National Pest Plant Accord (NPPA)
- Weedbusters NZ: website and resources
- AgResearch: AgPest website
- Massey University: New Zealand Weeds Database.

Citizen science:

- New Zealand Bio-Recording Network (NZBRN): iNaturalist NZ – Mātaki Taiao website, and related apps: iNat, Seek, Find-A-Pest.

Name of database/resource	Manaaki Whenua – Landcare Research (MWLR): New Zealand Organisms Register (NZOR)			
Purpose/rationale	To create a publicly accessible, online, accurate, authoritative, comprehensive and continuously updated catalogue of taxonomic names of all NZ biota.			
Development and maintenance	**Development timeline**	Established 2006		
	Developer	MWLR, under direction of the NZOR Steering Group.		
	Maintainer	MWLR		
	Update frequency	Updated weekly from registered data providers (DOC, MWLR, NIWA).		
	Status	Active ☒	Dormant☐	Terminated☐
	Main contributors	MWLR provides project leadership, technical support and hosting of the system. MWLR, NIWA, Te Papa, and DOC are data providers. The NZOR Steering Group contributes to deciding future directions. Members of Steering Group include representatives of the BioHeritage Challenge, DOC, local government, MPI, Te Papa, and MWLR.		
	Development costs	Not supplied.		
	Ongoing resourcing / maintenance costs	Originally developed with funding from the now-defunct Terrestrial and Freshwater Biodiversity Information System (TFBIS) Programme. Ongoing resourcing for support, maintenance and enhancement is challenging. Funding to support curatorial work in the source provider databases is mixed. Following termination of TFBIS, NZOR has received periodic financial support from MWLR, DOC, MPI, and MfE.		

Data content	**Data type**	Author authorities ☒	Extensive synonymy ☒	Mapping/ geodata ☐
	Data/information quality	Data follow international Biodiversity Information Standards (TDWG). Accurate, authoritative and comprehensive. Organism names are based on scientific publications and the database uses a highly structured taxonomic data model (meaning that the database is designed to handle the complexities of taxonomic names). See www.nzor.org.nz/data-quality-and-use for other comments on data quality.		
	Overall scope/coverage	• Aims to include taxonomic data for all taxa relevant to NZ – whether present in NZ or overseas. • Aims to include all NZ biota (e.g. algae, amphibians, arachnids, arthropods, bacteria, birds, centipedes and millipedes, crustaceans, ferns, fishes, fungi, insects, lichens, liverworts, mammals, marine worms, mosses, protozoans, reptiles, seed plants). • Currently >154,000 taxon names, >95,000 accepted names, >69,000 taxa present in NZ (a running total is provided on the home page at www.nzor.org.nz). • Names have authorship and publication details when provided by source databases. • Presence in NZ ('biostatus') of organisms is recorded.		
	Data/information strengths	Based on an application programming interface (API), providing flexibility for the delivery of services and information. The website services include a function to perform batch matching of names in NZOR to assist adoption, etc. There is an automated process to fully integrate disparate and sometimes conflicting resources. Highly structured database architecture that accommodates all the complexity of taxonomic rules and structure to accurately manage names of any taxonomic rank and nomenclatural code, as well as vernacular and trade names.		

	Data/information weaknesses	NZOR data are only as good as what are provided. NZOR is primarily intended as infrastructure, so the focus is on the provision of the API. A simple website (currently using the less secure http protocol rather than https) has been provided over the top of these services for users to search using name strings and to expose the API and other services. After searching, users are able to apply search facets to filter the results, although these may not meet all users' needs. To achieve good taxonomic coverage some data were provided from static (non-maintained) resources (e.g. Gordon 2012; King et al. 2009; Vink 2011). NZOR therefore reflects the lack of availability of 'live' well-managed and -curated taxonomic data and expertise for some taxonomic groups in NZ. There is an intent to address this in part by integrating with international names databases when resources permit.
	Data/information gaps	NZOR reflects the availability and coverage of taxonomic data within NZ, as well the funding/availability and willingness of agencies to provide data they do hold. One of the original purposes of NZOR was to document and highlight gaps in the taxonomic data for NZOR, but funding to undertake and address these gaps has not been available. Exotic cultivated flora in NZ is a significant and recognised gap, in NZOR and Ngā Tipu o Aotearoa – New Zealand Plants database (PND). See contributing resources for gaps that have been identified.
	Invasive plant relevance	NZOR provides the 'glue' for information systems to exchange data about invasive plants and other biota. Exchanges the same plant names with the PND, including invasive plants. Neither of these plant names databases have biostatus filters from which to retrieve lists of invasive plants for NZ. For that you have to use the interconnected Flora of New Zealand Online (www.nzflora.info/browse.html).
Primary contact(s)	**Name(s)**	Aaron Wilton

	Email	wiltona@landcareresearch.co.nz
Access	**Web**	www.nzor.org.nz
	Publications	Scoping document (Carver et al. 2007): www.nzor.org.nz/content/documents/nzor-scope.pdf.
User base	MWLR, NIWA, Te Papa, DOC, MPI Biosecurity NZ, EPA, local government agencies, museums, universities and NGOs. An average of 1,047 website sessions per month for 2019.	
Relationship to other resources	Names for some sections of the biota were originally harvested from static content, especially *The New Zealand Inventory of Biodiversity*, Vol. 1–3 (Gordon 2009, 2011, 2012). NIWA and DOC data were imported manually from their databases. Plant, land invertebrate, fungal and bacterial names are dynamically exchanged with three other MWLR-maintained databases: • Ngā Tipu o Aotearoa – New Zealand Plants database: https://nzflora.landcareresearch.co.nz/ • Ko te Aitanga Pepeke o Aotearoa – New Zealand Land Invertebrates database: https://nzinverts.landcareresearch.co.nz/ • New Zealand Fungi and Bacteria (NZFUNGI) database: https://nzfungi2.landcareresearch.co.nz/ In accord with the original scope of NZOR, there are ambitions to dynamically connect to other NZ resources, such as those held by MPI, and international names databases. International names databases include: • Global Biodiversity Information Facility (GBIF; www.gbif.org) • The Plant List (TPL; www.theplantlist.org) • World Flora Online (WFO; www.worldfloraonline.org) • International Plant Names Index (IPNI; www.ipni.org).	
Summary	• An ambitious project that has succeeded in its original target of providing a single, definitive registry of >100,000 organism names relevant to NZ. • An innovative taxonomic names database architecture with further potential to interconnect / exchange data to achieve less duplication and better names management of biota in NZ.	

Name of database/resource	Manaaki Whenua – Landcare Research (MWLR): Ngā Tipu o Aotearoa – New Zealand Plants database (PND)			
Purpose/rationale	To provide public online access to the scientific names of the NZ flora accepted by the Allan Herbarium (CHR), as well as associated vernacular (common and Māori) names, synonyms, incorrectly applied names, biostatus (presence in NZ), taxonomy, and literature.			
Development and maintenance	**Development timeline**	Established 1999		
	Developer	Aaron Wilton (Herbarium Database Manager, MWLR)		
	Maintainer	• Plant names: Ines Schönberger (Manager Allan Herbarium, MWLR) • Platform: Informatics staff, MWLR.		
	Update frequency	Continually updated and keeps track of new taxonomic changes. The database is refreshed twice a week to federate names data to related resources.		
	Status	Active ☒	Dormant☐	Terminated☐
	Main contributors	Updates are driven by botanical revisions published by NZ and international researchers. Taxonomic revisions are circulated to a group of NZ botanists to see if they agree with accepting the findings of these publications. Upon agreement, the new names and status are incorporated into the PND.		
	Development costs	Not supplied.		
	Ongoing resourcing / maintenance costs	Revising the names in the database is currently limited to 0.2 FTE for all plant groups (lichens, liverworts, mosses, ferns, freshwater algae and seed plants). This excludes database platform maintenance.		
Data content	**Data type**	Author authorities ☒	Extensive synonymy ☒	Mapping/ geodata ☐
	Data/information	• Data follow international Biodiversity Information Standards (TDWG).		

	quality	• Accurate, authoritative and comprehensive. • Names data are based on extensive scientific publications, which are kept up to date. • See: https://nzflora.landcareresearch.co.nz/WebForms/DisplayForm_dataquality_NZFlora.aspx
	Overall scope/coverage	• Lichens, liverworts, mosses, ferns, freshwater algae and seed plants of NZ. • >46,000 botanical names, including accepted names, synonyms and incorrectly applied names. • Authorship and publication details. • Presence in NZ ('biostatus') stated (e.g. exotic, naturalised, indigenous, cultivated).
	Data/information strengths	A comprehensive and functional resource, which has an elaborate database architecture that accommodates taxonomic rules and structure to accurately manage names. This database is strong on NZ native and fully naturalised species.
	Data/information weaknesses	Lack of resources means that it's difficult to keep treatments of the naturalised species concordant with non-NZ resources (e.g. so that the same names are accepted in the PND and the Australian Plant Name Index databases). The dated user interface is in need of a visual refresh (planned to be updated).
	Data/information gaps	Non-native species in cultivation in NZ are within scope but not as well represented as native and fully naturalised species.
	Invasive plant relevance	The biostatus 'Fully Naturalised' covers plant taxa that produce self-maintaining populations in the wild. This biostatus is more or less analogous to invasive plants. There are >2,700 'Fully Naturalised' taxa accepted in the PND (and NZOR) databases, a figure retrievable from the associated Flora of New Zealand Online (www.nzflora.info/browse.html).
Primary contact(s)	**Name(s)**	Aaron Wilton and Ines Schönberger

	Email	PlantInfo@landcareresearch.co.nz
Access	**Web**	https://nzflora.landcareresearch.co.nz
	Publications	Annual checklists. Quarterly reports of the changes to the data in the PND and checklists of the NZ flora are compiled and accessible in the MWLR DataStore (https://datastore.landcareresearch.co.nz/dataset?q=Plants+Names+Database+Quarterly&sort=metadata_modified+desc).
User base	• Botanists, ecologists, researchers, regulators. • MWLR, NIWA, Te Papa, DOC, MPI Biosecurity NZ, EPA, local government agencies, museums, universities and NGOs. • An average of 1,055 website sessions per month for 2019.	
Relationship to other resources	Names to build the original database were sourced from: • Flora of New Zealand series – print (1961–2000) and digitised (https://floraseries.landcareresearch.co.nz/pages/index.aspx) versions • *Common Names of Plants in New Zealand* (Nicol 1997). Actively exchanges names data with: • New Zealand Organisms Register: www.nzor.org.nz • Flora of New Zealand Online: www.nzflora.info/about.html • Allan Herbarium (CHR) Systematics Collections Data (SCD): https://scd.landcareresearch.co.nz The Australian equivalents of the PND could be seen as: • Australian Plant Name Index (APNI): https://biodiversity.org.au/nsl/services/apni • Australian Plant Census (APC): https://biodiversity.org.au/nsl/services/APC	
Summary	• A comprehensive and authoritative taxonomic database providing accepted botanical names, synonyms, common names and Māori names for the NZ flora. • Exchanges names data with several related resources. • Publicly accessible and (along with NZOR) should be seen as the primary source of plant names in NZ.	

Name of database/resource	Manaaki Whenua – Landcare Research (MWLR): Systematics Collections Data (SCD)			
Purpose/rationale	To provide public access to specimen and culture data from the Allan Herbarium (CHR), the International Collection of Micro-organisms from Plants (ICMP), the National New Zealand Flax Collection (FLAX), the New Zealand Arthropod Collection (NZAC) and the New Zealand Fungal and Plant Disease Collection (PDD). This table will concentrate on the Allan Herbarium (CHR) SCD resource as this is the most relevant to invasive plants.			
Development and maintenance	**Development timeline**	Accessible to the public 2013		
	Developer	Aaron Wilton (Herbarium Database Manager, MWLR)		
	Maintainer	• Specimen data: Kate Boardman (Database Administrator, Allan Herbarium, MWLR) • Platform: Informatics staff, MWLR.		
	Update frequency	Updated continuously, and publicly available soon after changes are made to specimen and culture records in the internal databases.		
	Status	Active ☒	Dormant☐	Terminated☐
	Main contributors	Herbarium specimens are collected from living plants in the wild and in cultivation by botanists and ecologists. Specimens collected by pest plant officers from regional councils, and those from Land Use and Carbon Analysis System (LUCAS) and DOC Tier 1 Inventory and Monitoring (I & M) plots, provide valuable records. Specimens are pressed, dried, mounted, labelled with collection details, assigned a unique Allan Herbarium (CHR) number, databased, and accessioned into the herbarium in perpetuity. Scanning of the accessioned specimens is conducted mainly by Friends of the Allan Herbarium on a voluntary basis.		
	Development costs	Not supplied.		

	Ongoing resourcing / maintenance costs	Upkeep and maintenance are partially supported by SSIF funding from MBIE's Science and Innovation Group. Additional funding for the digitisation of some targeted specimen records has in the past been provided by the defunct TFBIS Programme, the Ministry of Foreign Affairs and Trade, and one-off funding from the Andrew W. Mellon Foundation.		
Data content	**Data type**	Author authorities ☒	Extensive synonymy ☒	Mapping/ geodata ☒
	Data/information quality	Data follow international Biodiversity Information Standards (TDWG). The limitations, as cited on the SCD introduction page at www.landcareresearch.co.nz/resources/data/systematics-collections-data, are: • the data are provided on an 'as is' and 'as available' basis. • the data are presented as they have been recorded on the specimens and cultures • some of the data may be inaccurate, incomplete and/or imprecise, including localities and identifications of specimens and cultures. Not all specimens or cultures held by a given collection have been entered into the database.		
	Overall scope/coverage	>296,000 herbarium specimens have been databased out of an estimated total of 820,000 specimens held in the Allan Herbarium (CHR).		
	Data/information strengths	A comprehensive set of filters are available to refine user search results. Provides access to all databased records (c. 50% of total holdings) at the Allan Herbarium – including NZ and foreign specimens. Although it has a NZ emphasis, collection data of specimens from other countries but housed at CHR are included in this resource. Full specimen label details are openly accessible, including: • accession number (CHR)		

		• botanical name • locality • georeference • altitude • specimen notes. Images of herbarium specimens are available for some records. Registered users have additional privileges, including the ability to download specimen data in CSV format.
	Data/information weaknesses	Has geodata but no in-built map view, which is out of scope. It would be useful to be advised in the SCD website FAQs of the related resources provided by the Australasian Virtual Herbarium (AVH) and the Global Biodiversity Information Facility (GBIF), both of which do provide mapping. Some records have georeference errors. Incomplete digitisation of the collection – priority is given to biosecurity species, threatened species and research priorities. Since the formation of CRIs, specimens collected by MWLR researchers are prioritised to support funded projects at the time. This introduces collection bias and there is limited scope for blanket collections of multiple species at given localities.
	Data/information gaps	About 48% of the specimens at CHR have been databased. This contrasts with 100% coverage in other NZ herbaria, which have significantly fewer holdings. The Allan Herbarium (CHR) is the largest herbarium in NZ.
	Invasive plant relevance	Numerous holdings of invasive plants. Herbarium specimen database searches are valuable in helping establish the dates and extent of spread – from first introduction in NZ to full naturalisation of invasive plants. Specimens collected by regional council pest plant officers for the Allan Herbarium plant identification service can provide valuable range extensions and first records of invasive plants.
Primary contact(s)	**Name(s)**	Aaron Wilton

	Email	wiltona@landcareresearch.co.nz
Access	**Web**	• Introduction page: www.landcareresearch.co.nz/resources/data/systematics-collections-data • Direct access: https://scd.landcareresearch.co.nz
	Publications	N/A
User base	An average of 862 website sessions per month for 2019. Likely to have a narrow user base, as this database is intended primarily for researchers who require access to specimen collection data.	

Relationship to other resources	• Systematics Collections Data (SCD) exchanges names with the Ngā Tipu o Aotearoa – New Zealand Plants names database (PND).
	• The Allan Herbarium is part of the New Zealand National Herbarium Network of 16 operating herbaria (www.nzherbaria.org.nz), some of which also provide herbarium specimen data on their respective websites, such as:
	  ○ Auckland War Memorial Museum (AK): www.aucklandmuseum.com/discover/collections-online/search
	  ○ National Forestry Herbarium, Rotorua (NZFRI): http://nzfri.scionresearch.com/nzfri/Explore
	  ○ Museum of New Zealand – Te Papa Tongarewa (WELT): https://collections.tepapa.govt.nz/taxon/38786.
	• Provides herbarium specimen data to the Australasian Virtual Herbarium (AVH). The AVH search at https://avh.ala.org.au/search/#tab_advanceSearch can simultaneously search multiple herbaria, compared to an Allan Herbarium (CHR)-only search through the MWLR SCD portal.
	• Provides herbarium specimen data to the Global Biodiversity Information Facility (GBIF; www.gbif.org), which combines datasets from various sources, including those from iNaturalist (www.inaturalist.org), and adds a mapping faculty.	

Summary	• Provides open and accessible specimen and culture data for MWLR's Nationally Significant Collections, including CHR specimen data. • A granular, information-rich resource aimed at researchers.	

Name of database/resource	Manaaki Whenua – Landcare Research (MWLR): New Zealand National Vegetation Survey (NVS) Databank	
Purpose/rationale	The aim is to ensure ongoing, up-to-date delivery of NZ's vegetation plot data to enhance fundamental understanding of our biota and ecosystems, and to meet conservation and biosecurity priorities and sector needs. The NVS databank is NZ's primary repository for plot-based ecological datasets on vegetation structure and composition, and aims specifically to: 1. provide archival data storage of nationally important datasets 2. enable archived data to be made available to users, while protecting the interests of data providers 3. encourage users of archived data to provide some benefit that enhances NVS, as an in-kind contribution.	
Development and maintenance	**Development timeline**	• 1940s–50s: first national-scale, plot-based forest surveys • 1960s: standardised methods for inventory and monitoring of native vegetation developed • Late 1960s: beginning of digitisation of data and development of software tools for data entry and analysis • Late 1980s: process for centrally archiving electronic and hard-copy data formalised • 1998: NVS accorded status of Nationally Significant Database • 2001: data migrated from outdated platform to SQL relational database • 2002: NVS website built • 2003: formal assessment of end-user needs • 2008: current database system implemented • 2009: release of stand-alone NVS Express tool to enable those external to MWLR to digitise data • 2015: website-based search redeveloped to improve data discoverability and enable users to easily request/download data
	Developer	MWLR, drawing on extensive datasets of predecessor organisations and developing the NVS data platform. Susan Wiser (Senior Scientist, MWLR) is the NVS Director.
	Maintainer	• NVS Database Manager • Data entry staff (MWLR) • Platform: Informatics staff, MWLR.

	Update frequency	Updated continuously; updates are available online after monthly website refreshes. Level 1 datasets are automatically available on demand, and Level 2 datasets are made available via an automated process where permission is granted by the data owner.		
	Status	Active ☒	Dormant☐	Terminated☐
	Main contributors	Plot data are recorded in the field by plant ecologists from a wide range of organisations. Early data collection efforts were undertaken by the New Zealand Forest Service, Department of Lands & Survey, and DSIR Botany Division. Ongoing surveys and research are carried out by DOC, regional councils, universities, private consultants and MWLR, which are continually providing new data to NVS. The specific programmes DOC Tier 1 Inventory & Monitoring and MfE Land Use and Carbon Analysis System (LUCAS) plots provide major ongoing national-scale field data to NVS.		
	Development costs	Initial development funded by NZ Forest Research Institute is unknown.		
	Ongoing resourcing / maintenance costs	Upkeep and maintenance are largely supported by SSIF funding from MBIE's Science and Innovation Group. Currently NVS receives $440,000 to $467,000 SSIF infrastructure funding per annum.		
Data content	**Data type**	Botanical names ☒	Extensive synonymy ☐	Mapping/ geodata ☒
	Data/information quality	The NVS data model is based on international schema (including TDWG Biodiversity Information Standards) and best practice. NVS has a number of inbuilt data validations to ensure data are of a consistently high standard. Data accuracy and protocols are explained at: https://nvs.landcareresearch.co.nz/About/Index An overview of the NVS data model is at:		

		https://nvs.landcareresearch.co.nz/Content/ModelDocumentation/NVSDataModelOverview_files/NVS%20Data%20Model%20Overview.htm Data are aggregated under several levels of ownership: • Level 1.0 (public datasets) • Level 2.0 (restricted datasets) • Level 2.9 (restricted access location-sensitive datasets) • Level 3.0 (private datasets). Data are provided on an 'as is' and 'as available' basis.
	Overall scope/coverage	• >109,000 vegetation survey plots • >25,000 permanent plots • 8,372 indigenous and exotic plant taxa • Broad geographical coverage, from Northland to Stewart Island, and the Kermadec and Chatham Islands • Broad ecosystem coverage, from coastal areas to forests to high alpine
	Data/information strengths	A very comprehensive and unique dataset. The website delivers abundant information, guides, and advice on how to record, contribute, extract and analyse data. Communication with users is efficient and feedback is quickly incorporated. Data within NVS support reporting requirements for the Convention on Biological Diversity, the Framework Convention on Climate Change, the Resource Management Act, State of Environment, and the Montreal Process, and for government departments, such as DOC. Species occurrence data from the NVS databank are provided to the Global Biodiversity Information Facility (GBIF). NVS is listed in the Global Index of Vegetation Databases www.givd.info
	Data/information weaknesses	For most datasets, overall error rates are low. Inconsistencies and errors can persist as some problems detected by data validations cannot be resolved without returning to the field site.

		The very large quantity of species occurrence records means that not all records are supported by herbarium vouchers or photographs. As such, it can be difficult to reconcile likely plant misidentifications and the implications of changes in taxon concepts over time (e.g. where a taxonomic revision has divided one species into two or more). Some obscure places in the website had out-of-date information. These were promptly updated when pointed out to the NVS team during the compilation of this summary table.
	Data/information gaps	There is a large backlog of hard-copy plot sheets to be accessioned into NVS and digitised. However, this backlog is catalogued.
	Invasive plant relevance	Plots sample natural vegetation across the spectrum of successional stages from areas recovering from anthropogenic disturbance to those that are largely intact. Plots that record total plant species composition record both native and introduced plants. Introduced plants occur in both recently disturbed areas and intact habitats that have been invaded.
Primary contact(s)	**Name(s)**	NVS Database Manager
	Email	nvs@landcareresearch.co.nz
Access	**Web**	https://nvs.landcareresearch.co.nz/Home/Index
	Publications	A list of recent publications (within the last 5 years) based on data archived in the NVS databank and NVS annual reports (2002–2019) can be downloaded from: https://nvs.landcareresearch.co.nz/Resources/Publications
User base	NVS has more than 500 registered users. Useful summaries of data users are in the NVS 2018/19 annual report at: https://nvs.landcareresearch.co.nz/content/NVS%20annual%20report%202018-2019.pdf (sections 8, 12, & 13, and the data providers named in section 2). Users include DOC, MfE, MPI, local government (e.g. regional councils, territorial authorities), researchers from NZ CRIs (e.g. MWLR, Scion), NZ and overseas universities, ecological consultants, and other interested parties. An average of 415 website sessions per month for 2019.	

Relationship to other resources	• NVS taxon names are linked to Ngā Tipu o Aotearoa – New Zealand Plants names database (PND). • Snapshotted summaries and versions of NVS datasets that support scientific publications are made available via the MWLR Research Datastore: https://datastore.landcareresearch.co.nz/. • All Level 1 (public access) data are shared with the Global Biodiversity Information Facility (GBIF). This is refreshed monthly. • NVS contributes data to the sPlot Global Vegetation Database (www.idiv.de/?id=176&L=0), the largest repository for plant community data in the world, with the goal of understanding global patterns in plant diversity across facets, biomes and scales. • NVS contributes data to the Global Forest Biodiversity Initiative (www.gfbinitiative.org), which supports cutting-edge research and policy-making in forest science and related initiatives. • NVS also contributes data to the global Botanical Information and Ecology Network (https://bien.nceas.ucsb.edu/bien/) and via BIEN to the NatureMap initiative (https://explorer.naturemap.earth/).
Summary	• Makes available field vegetation plot data spanning 70 years. The website has extensive documentation and guides to help users and contributors. • A granular, information-rich resource aimed primarily at researchers, land managers, and international biodiversity data synthesis efforts.

Name of database/resource	Manaaki Whenua – Landcare Research (MWLR): DataStore Group: NZ Non-native Flora Traits & Distributions			
Purpose/rationale	To house and provide easily accessible trait data for non-indigenous, particularly naturalised and invasive, plant species in NZ in support of research and decision-making. The aim is for this Group to include links to all datasets uploaded to DataStore that include information on non-native plant attributes.			
Development and maintenance	**Development timeline**	• 2018–2019: compilation of relevant data from multiple datasets housed within MWLR and partner organisations, as well as from global databases (TRY-db and GBIF). • 2019: DataStore Group created to provide a single site linking to all DataStore datasets with information on plant attributes. • 2019–2020: first datasets uploaded to Group.		
	Developer	MWLR, with initial efforts led by Angela Brandt, building on previous datasets compiled by researchers both inside and external to MWLR and drawing from global databases.		
	Maintainer	• DataStore Data Manager • MWLR researchers (Angela Brandt)		
	Update frequency	As new datasets are produced or current datasets are updated. Likely to be irregular as it depends on resourcing of projects that compile or collect relevant data.		
	Status	Active ☒	Dormant☐	Terminated☐
	Main contributors	Any researcher with a DataStore account can contribute datasets (current lead contributors to the NZ Non-native Flora Traits & Distributions Group include Angela Brandt and Tom Etherington).		
	Development costs	Labour costs for developing the initial datasets uploaded to the DataStore Group are estimated at $100,000 over 2 years, supported jointly by SSIF funding from MBIE's Science and Innovation Group and the MBIE Endeavour programme 'Winning Against Wildings'. Creating the DataStore Group was also supported by the resourcing of the DataStore site		

		and its development staff.		
	Ongoing resourcing / maintenance costs	Involves continued resourcing of the DataStore site and support staff at a minimum, as well as funding of projects that will compile and/or collect more data or update the existing datasets on non-native plant attributes. As an example, the cost of updating the existing growth form (https://datastore.landcareresearch.co.nz/dataset/nz-non-native-flora-growth-forms-2019) and distribution (https://datastore.landcareresearch.co.nz/dataset/nz-naturalised-flora-distribution-2019) datasets to incorporate annual updates to the checklists provided by PND is estimated at $14,000.		
Data content	**Data type**	Author authorities ☐	Extensive synonymy ☐	Mapping/ geodata ☐
	Data/information quality	• Data are derived from GBIF and MWLR databases (including the PND), which follow best-practice international standards. • Growth form data are compiled from regional floras, herbaria and primary literature, where available, or from horticultural or nursery websites. • Quantitative trait data are compiled from primary data collected within NZ (by MWLR researchers or collaborators) and globally (accessed via the TRY database).		
	Overall scope/coverage	There are four current datasets: • invasive Pinaceae traits 2018: three traits (specific leaf area, leaf nitrogen concentration, and wood density) for 34 species. • NZ native vs. naturalised tree leaf traits 2019: specific leaf area and leaf nitrogen concentration of 108 indigenous and 73 naturalised NZ trees • NZ naturalised flora distribution 2019: occurrence of naturalised plant species within each of NZ's 16 mainland political regions according to records in the GBIF. • NZ non-native flora growth forms 2019: growth form, lifespan, and maximum height of 2,806 NZ non-native flora.		
	Data/information strengths	• Datasets are publicly accessible. • References for all information are clearly provided to enable error checking and updating in the event		

		of taxonomic changes. • Updated or new information can be added to the DataStore Group by any users, and the site is institutionally maintained. • The four datasets currently in the DataStore Group represent the most up-to-date, comprehensive and easily accessible datasets of non-native flora attributes available for NZ that are ready to use for research purposes.
	Data/information weaknesses	• No automatic validation or error-checking processes have been used for these datasets – accuracy relies on the carefulness of dataset authors. • The datasets are time-stamped as they do not automatically update with taxonomic or status changes for non-native species. • Updates to datasets to correct errors and update taxonomy or status are not systematic but require identification of need and pursuit of adequate resourcing.
	Data/information gaps	• Several key attributes of non-native plants that are likely to be useful to researchers and land managers are not included in the current datasets available. For example, the previous databases on which this project was initiated also included data on species' regions of origin, data first recorded in NZ, NZ habitats occupied, flowering time and dispersal mode. Certain quantitative traits (e.g. seed size) are also notably absent. • Three of the four datasets currently available are for subsets of the non-native flora only. In the case of most quantitative plant traits, such data are not readily available (and often have not been measured) for all non-native plants in NZ. In particular, these traits have not all been measured on specimens growing within NZ. • The current datasets indicate species' status as a DOC Environmental Weed (*sensu* Howell 2008) but do not indicate which species are in regional or other national pest plant lists.
	Invasive plant relevance	The datasets draw on comprehensive lists of non-native plants growing outside cultivation in NZ as compiled by the PND and include their status as fully naturalised or casually occurring species. Also, species' status as a DOC Environmental Weed (*sensu* Howell 2008) is indicated in

		multiple datasets.
Primary contact(s)	**Name(s)**	DataStore Data Manager
	Email	DataManager@landcareresearch.co.nz
Access	**Web**	https://datastore.landcareresearch.co.nz/group/nz-non-native-flora-traits
	Publications	Sapsford et al. 2020. Towards a framework for understanding the context-dependence of impacts of non-native tree species. *Functional Ecology* 34(5): 944–955. https://doi.org/10.1111/1365-2435.13544 Brandt et al. In review. Naturalised plants transform the composition and function of the NZ flora. *Biological Invasions*.
User base	Ecologists, researchers, biodiversity and biosecurity managers from local to national scale.	
Relationship to other resources	• Part of various datasets available on the MWLR DataStore repository. • Botanical names are sourced from Ngā Tipu o Aotearoa – New Zealand Plants names database (PND). • Data are also sourced from the Global Biodiversity Information Facility (GBIF; www.gbif.org) and TRY Plant Trait Database (www.try-db.org/TryWeb/Home.php), which combine datasets from many sources.	
Summary	Along with other Datastore repositories, the NZ Non-native Flora Traits & Distributions datasets provide granular data accessible to researchers.	

Name of database/resource	Ministry for Primary Industries (MPI): Biosecurity New Zealand: Plants Biosecurity Index (PBI)			
Purpose/rationale	An online biosecurity database of plant species that are considered not to be new organisms under the HSNO Act 1996. The PBI also identifies associated Import Health Standards (IHS) and other criteria that must be met before the species (as seed and nursery stock) can be imported into NZ. Also lists a set of unwanted species and species prohibited from entry.			
Development and maintenance	**Development timeline**	Development of the PBI began in preparation for the implementation of the new organism provisions of the Hazardous Substances and New Organisms Act 1996 (HSNO), on 29 July 1998, as a working tool to designate taxa acceptable for importation, based on plants considered to be already present in NZ. Once the new organism provisions of the Act had come into force, the PBI was updated with new species as they were approved for release or determined not to be new organisms under the Act. MWLR was commissioned to produce a list of names of plant species present in NZ. This list, the AllNZspp database was developed from 1996 and handed to the Ministry of Agriculture and Forestry in 2000 and provided the initial data for the PBI.		
	Developer	Ministry of Agriculture and Forestry, until April 2012; from then MPI.		
	Maintainer	MPI		
	Update frequency	As needed, subject to approval from a senior advisor or team manager in the MPI Plants & Pathways Directorate. Updates are made on an *ad hoc* basis, when: • decisions are made about the presence/absence/taxonomy of a species in NZ • the EPA approves a new organism for full release into NZ, and • the new organism status of an organism is removed. The PBI was most recently updated in May 2020.		
	Status	Active ☒	Dormant☐	Terminated☐

	Main contributors	MPI add or modify species names and change the import status. The EPA provides new names from their presence in NZ determinations. Horticulturists and other professionals have requested that MPI add names to the PBI, but the correct legislative pathway for recognising species presence is via the EPA. After implementation of the HSNO Act, the EPA has employed two mechanisms to determine whether a plant species is a new organism or not; statutory (s26) and non-statutory decision-making. Many species were added through the latter, it being an easier and less costly route. Based on legal advice, the EPA ceased non-statutory decision-making at least 8 years ago. This has considerably slowed the addition of new plant species names to the PBI.		
	Development costs	Approximately $200,000 in 1997.		
	Ongoing resourcing / maintenance costs	Not supplied.		
Data content	**Data type**	Author authorities ☐	Extensive synonymy ☐	Mapping/ geodata ☐
	Data/information quality	Botanical name handling is relatively weak. • There are major limitations in managing names within the current database structure. • Extensive listings of plant names are difficult for MPI to keep up to date. • The accuracy and validity of the existing names are unknown. • New species known to be present in NZ are not consistently added, because this is not the purpose of the PBI. Names are only added after approval by the EPA and MPI.		
	Overall scope/coverage	• Currently 29,684 plant names. • Names for 411 species prohibited from entry. • There are numerous import specifications for both seed material and nursery stock.		
	Data/information	• The PBI is the most comprehensive online listing		

	strengths	of plants considered not to be new organisms under the HSNO Act 1996. • The import specification standards for seed and nursery stock are discoverable and well managed.
	Data/information weaknesses	• A dated (but functional) interface. • No online introductory/explanatory notes of the PBI. • Does not list all plant species that were present in NZ immediately prior to 29 July 1998. • Largely species-based (which meets legislative requirements but provides a limited measure of genetic diversity). • Limited synonyms (which means few cross-references to accepted names) • No plant families (from which to provide clarity of identity and relationships) • No higher taxonomic hierarchy • No author authorities (from which to establish correctness of name) • No publication references to plant names • No connections to other databases • Outdated taxonomy.
	Data/information gaps	• Numerous species are known to be present in NZ but are not listed on the PBI.
	Invasive plant relevance	The PBI has an 'Entry prohibited' filter that retrieves 411 species that are known to be highly invasive. Some of these species are absent from NZ while others are established and widespread environmental weeds. The greatest source of new naturalisations is plants escaping cultivation within NZ (rather than new incursions from overseas) – hence this comprehensive listing is useful to assess the potential of new invasives.
Primary contact(s)	**Name(s)**	The responsibility for updating the index sits within the Plants and Pathways Directorate at MPI.
	Email	PlantImports@mpi.govt.nz
Access	**Web**	www1.maf.govt.nz/cgi-bin/bioindex/bioindex.pl
	Publications	Article outlining the PBI: www.rnzih.org.nz/RNZIH_Journal/Pages_8-

		9_from_2009_Vol12_No2.pdf
User base	MPI Biosecurity New Zealand staff, plant importers, horticulturists, plant breeders.	
Relationship to other resources	• The initial names data for the PBI originated from an MWLR Access database file (AllNZspp) beginning in about 1997 and handed to the then Ministry of Agriculture and Forestry in 2000. MAF contracted MWLR to construct the database. • The PBI is a stand-alone database. • There are no links to or interconnections with NZOR.	
Summary	A public database that does a good job of handling the import and other regulatory standards, but is weak as a comprehensive resource of listing plant species considered not to be new organisms under the HSNO Act 1996, and weak at managing the complexity of botanical names.	

Name of database/resource	Ministry for Primary Industries (MPI): Biosecurity New Zealand: Unwanted Organisms Register (UOR)			
Purpose/rationale	To provide a searchable register/database of organisms that a chief technical officer believes are capable, or potentially capable, of causing unwanted harm to any natural and physical resources or human health. Section 164C(2) of the Biosecurity Act (added by amendment on 26 November 1997 by s108 of the Biosecurity Amendment Act 1997) requires that the Director General keep a register of all organisms notified as being unwanted organisms.			
Development and maintenance	**Development timeline**	First developed during about 1999–2001.		
	Developer	Ministry of Agriculture and Forestry until April 2012; from then MPI.		
	Maintainer	MPI		
	Update frequency	Often, as required.		
	Status	Active ☒	Dormant☐	Terminated☐
	Main contributors	MPI Biosecurity New Zealand		
	Development costs	Not supplied.		
	Ongoing resourcing / maintenance costs	Minimal		
Data content	**Data type**	Author authorities ☐	Extensive synonymy ☐	Mapping/ geodata ☐
	Data/information quality	• 97.8% of the plant names are correctly spelt. • 89.7% of the plant names in the UOR are accepted in international databases (others may be invalid, unmatched, or synonyms of accepted spp.).		
	Overall scope/coverage	• 29 diverse types of unwanted organisms are treated, including viruses, bacteria, insects, mammals, plants. • 271 unwanted plant species.		

	Data/information strengths	• Unwanted organisms are searchable and also filterable by many criteria. • Links from each species result provide access to further information such as synonyms and a taxonomic hierarchy. • The spreadsheet data download is a useful feature.
	Data/information weaknesses	• Dated (but functional) interface. • The 'Government Dept.' filter is confusing due to repeated and outdated institutional names. • Because there are no links to explain what is meant by each category, some of the filter combinations do not retrieve data expected by casual end-users (e.g. Type: Plant; Category: Other Endemic Organism produces all exotic species and no NZ indigenous endemics; Type: Plant; Government Dept.: Department of Conservation does not yield a list of the 328 Environmental Weeds of NZ. • No author authorities (from which to establish correctness of name). • No published references to plant names. • No connections to other databases. • No links to any information relating to why an organism was placed on the UOR in the first place.
	Data/information gaps	If in scope, it would be useful to include NPPA and RPMP categories, which both also represent unwanted organisms. This could fill the void left following decommissioning of the now defunct MPI-maintained database 'Biosecurity activity and performance data', where users could retrieve which species were in which individual RPMP strategies. This need may be better served from Bionet.NZ.
	Invasive plant relevance	Retrieves a list of 271 unwanted plant species, all invasive or potentially harmful to the NZ environment, and the agencies responsible for managing them.
Primary contact(s)	**Name(s)**	Kim Crook
	Email	kim.crook@mpi.govt.nz
Access	**Web**	https://www1.maf.govt.nz/uor/searchframe.htm
	Publications	n/a

User base	Horticulturists, importers of plant material, MPI staff including Biosecurity NZ incursion investigators and frontline biosecurity officers. Web usage stats not supplied.
Relationship to other resources	• The Unwanted Organisms Register is a stand-alone database not interconnected with the PBI or NZOR.
Summary	A publicly accessible database that lists many criteria of unwanted organisms and the agencies responsible for managing them.

Name of database/resource	Manaaki Whenua – Landcare Research (MWLR): Flora of New Zealand Online (nzflora)			
Purpose/rationale	As stated at www.nzflora.info/about.html, the purpose is 'To provide New Zealand with a dynamic, continually updated, electronically-based Flora. It will be based on new systematic research and will bring together information from our network of databases and online resources. Users will have easy access to the most authoritative, accurate, and up to date information on New Zealand plants.'			
Development and maintenance	**Development timeline**	First online in 2010		
	Developer	MWLR		
	Maintainer	MWLR		
	Update frequency	Incorporates ongoing and scheduled production of new flora treatments published in fascicles. Automatic publications runs are monthly, but manual runs may be performed in between, as required, to publish new information.		
	Status	Active ☒	Dormant☐	Terminated☐
	Main contributors	Relies on information from the Allan Herbarium specimen database and the Plant Names Database. Authors who contribute taxonomic treatments, as stated at www.nzflora.info/publications.html, are: • P.J. Brownsey (Te Papa) • L.R. Perrie (Te Papa) • P.D. Champion (NIWA) • D. Glenny (MWLR) • K.A. Ford (MWLR) • P.B. Heenan (MWLR) • R.D. Smissen (MWLR) • J.E. Beever (MWLR Research Associate) • A.J. Fife (MWLR Research Associate, now retired).		
	Development costs	TFBIS and SSIF funding supported the development costs. Amount not supplied.		

	Ongoing resourcing / maintenance costs	Ongoing maintenance is funded by SSIF, with contributions from other agencies such as MPI.		
Data content	**Data type**	Author authorities ☒	Extensive synonymy ☒	Mapping/ geodata ☒
	Data/information quality	Data follow international Biodiversity Information Standards (TDWG). Taxonomic descriptions and associated names data are authoritative and generally highly accurate.		
	Overall scope/coverage	As currently stated in the running totals at www.nzflora.info/browse.html: • 8,021 taxa (native and naturalised, vascular and non-vascular, and aquatic and terrestrial plants) • 1,698 images • 375 dedicated weed profiles.		
	Data/information strengths	Incorporates rigorous taxonomic treatments, including full descriptions, sourced from published floras as well as new taxonomic treatments prepared exclusively for nzflora. Modern front-end and clean interface. The Browse page (www.nzflora.info/browse.html) includes a wide range of useful filters. Taxon profiles have: • classification that's navigable • nomenclature • description • biostatus (presence in NZ) • phenology (flowering and fruiting months) • bibliography. Built on a robust and elaborate back-end, drawing information from interconnected MWLR databases: • nzflora/eFlora Database • Ngā Tipu o Aotearoa – New Zealand Plants names database (PND) • Image Database • Specimen Database.		
	Data/information weaknesses	The nzflora website currently uses the less secure http protocol rather than https. The Botanical Group filter currently only has Gymnosperms		

		and Mosses; for some reason Angiosperms (Monocots and Dicots) and Pteridophytes (Ferns and allies) do not currently form part of this filter set. Distribution information on taxa is very useful, but currently limited to the 375 dedicated Weed Profiles (via an Australasian Virtual Herbarium map feed). There are no pop-up definitions to the technical terms: users must manually consult a glossary page at www.nzflora.info/glossary.html.
	Data/information gaps	• Many species are missing descriptions, especially for non-native taxa. • Image coverage for species range from good to poor. There is no current feed displaying images of scanned herbarium specimens. • Current priorities focus on incorporating new treatments rather than addressing some of the data/information gaps and errors for current taxa. Hence, user feedback for existing descriptions is seldom incorporated.
	Invasive plant relevance	Filters on the Browse page (www.nzflora.info/browse.html) currently allow users to retrieve: • 325 Environmental Weeds • 329 Regional Pests • 375 dedicated Weed Profiles • 1466 'Casual' taxa • 2725 'Fully Naturalised' taxa.
Primary contact(s)	**Name(s)**	Aaron Wilton (Editor-in-Chief)
	Email	eflora@landcareresearch.co.nz
Access	**Web**	Home page: www.nzflora.info
	Publications	The Flora of New Zealand publishes new taxonomic treatments as fascicles in PDF format (2014–). See www.nzflora.info/publications.html Mosses and ferns / fern allies have taken the highest priority, with treatments of other groups in preparation.

User base	• Botanists, ecologists, researchers, regulators. • MWLR, NIWA, Te Papa, DOC, MPI Biosecurity New Zealand, EPA, local government agencies, museums, universities and NGOs. • An average of 4,193 website sessions per month for 2019.
Relationship to other resources	• As noted, this resource draws from interconnected MWLR databases (nzflora database, Ngā Tipu o Aotearoa – New Zealand Plants names database, image database, specimen databases). • The 375 dedicated Weed Profiles were produced to complement the interactive key to the weed species of NZ. • Species descriptions, especially those derived from the printed floras, closely match, but are not dynamically connected to those housed on the New Zealand Plant Conservation Network (NZPCN) website (www.nzpcn.org.nz/flora/species).
Summary	A modern, information-rich, highly interconnected database-driven website, with powerful search and navigation capabilities. Would benefit from the infill of missing descriptions, distribution maps, and a larger image set. Likely to be highly under-resourced given its scope. Overlaps, and could be said to compete with, species descriptions on the NZPCN website (www.nzpcn.org.nz/flora/species).

Name of database/resource	New Zealand Plant Conservation Network (NZPCN): exotic plant species profiles and related resources			
Purpose/rationale	The NZPCN is an NGO, founded in 2003, devoted to the protection and restoration of NZ's indigenous plant life, including vascular plants, mosses, liverworts, hornworts and lichens. As stated on their homepage at www.nzpcn.org.nz, their vision is that 'the rich, diverse and unique native plant life of New Zealand is recognised, cherished and restored'.			
Development and maintenance	**Development timeline**	• 2003: initial build of website • c. 2010: a more complex build developed • 2012: facelift to improve the front-end usability and appearance • 2019–20: rebuilt with a new Content Management Framework (CMF), and some changes made to the front-end interface, including full touch screen responsiveness, and some rationalisations of content.		
	Developer	NZPCN National Council Members, made possible through major funding successes led by the late John Sawyer. The database-driven website was initially built by Anthony Archer of Propel.		
	Maintainer	• Peter de Lange, Colin Ogle and Matt Ward (botanical descriptions, vascular plant checklists) • Bill Campbell (administrator and newsletter editor) • Jesse Bythell (webmaster) • Robin Sallis (web developer).		
	Update frequency	Updated on a weekly, and sometimes daily, basis by the maintainers named above.		
	Status	Active ☒	Dormant☐	Terminated☐
	Main contributors	The majority of web maintenance and new content are contributed by volunteers: • members of the NZPCN, including the NZPCN council and co-opted members named at www.nzpcn.org.nz/nzpcn/council-members • Peter de Lange, who has written the majority of species pages (nearly 2,000) • the late John Sawyer, who mostly prepared about		

		300 content pages • 333 photographers, who contributed to the image galleries.		
	Development costs	The NZPCN resources were originally developed following multiple grants to the now defunct Terrestrial and Freshwater Biodiversity Information System (TFBIS) programme. Amount not supplied.		
	Ongoing resourcing / maintenance costs	The NZPCN haven't received any major funding since 2012 (TFBIS). The majority of ongoing work is done by volunteers. Revenue is used to support the NZPCN website, to run their NGO and to help fund events like conferences. Current sources of revenue are: • annual membership fees (typically $15–40; www.nzpcn.org.nz/membership/register) • an online shop (www.nzpcn.org.nz/nzpcn/shop) • donations (www.nzpcn.org.nz/nzpcn/donate) • sponsors (www.nzpcn.org.nz/nzpcn/sponsors) • conference fees.		
Data content	**Data type**	Author authorities ☒	Extensive synonymy ☐	Mapping/ geodata ☒
	Data/information quality	• Information is largely accurate. • Botanical names are accurate and up to date. • Corrections provided by users are rapidly responded to and incorporated.		

	Overall scope/coverage	• 5,041 native taxa: (www.nzpcn.org.nz/flora/species/?native=1)
		• 2,684 exotic taxa: (www.nzpcn.org.nz/flora/species/?native=0)
		• Numerous other pages and resources focused on the conservation of native plants, including information under the following headings:
		  ○ Flora
		  ○ Threats
		  ○ Ecosystems
		  ○ Publications
		  ○ Conservation
		  ○ NZPCN
		  ○ Help
		  ○ Contact Us.		

	Data/information strengths	Built on a modern and robust platform that has recently been upgraded. This makes it easy for web administrators to improve content. Old URLs usefully redirect to new locations. A comprehensive resource with a searchable database containing 1,741 documents (mostly digitised newsletters and articles from NZ botanical societies). For some species profiles there are comprehensive and original botanical descriptions (mainly prepared by Peter de Lange on vascular native species). Flora searches (www.nzpcn.org.nz/flora/species) can be made by scientific name, common name, and family name, and also filtered to retrieve native and/or exotic taxa, and many other parameters: • category (vascular, non-vascular, fungi) • structural class (17 parameters) • conservation status (14 parameters) • flower colour. Taxon profiles have information arranged under 28 or more headings, including: • common name • synonyms • family • authority • conservation status (current and previous) • brief description • distribution (text not mapping) • habitat • features. Since the recent upgrade, images use a modern slideshow script, which is a major improvement. The majority of vascular plant profiles have at least one image. On-click pop-up definitions for technical text terms are very useful to demystify these terms to a wider user base. Subscribed members can create a 'PDF Book' by selecting species. Other pages house a wealth of information, including: • regional and national plant lists (www.nzpcn.org.nz/publications/plant-lists) • Botanical Society journals and newsletters

		(www.nzpcn.org.nz/publications/botanical-society-journals) • a database that allows subscribed members to search for practitioners with particular skills and research interests.
	Data/information weaknesses	A self-contained resource that does not dynamically share data with external resources. A few issues were found with the flora search filters not retrieving taxa due to incorrect, or lack of, structural class scoring. Some of the more obscure website pages had out-of-date information. Legacy images in the species profiles were scanned at a low resolution and size; newer images are larger and higher resolution, although many are behind a members-only paywall.
	Data/information gaps	• Full species profiles with descriptions are focused on vascular native plants; many non-vascular and exotic species are missing, incomplete or exist as placeholder pages. • Image coverage for species range from good (for most vascular plants) to poor (for many non-vascular plants and exotics).
	Invasive plant relevance	The NZPCN's primary focus has been, and will continue to be, on native plants, particularly threatened native plants. Although they are not aiming to provide a detailed flora of exotic plants in NZ, at least three areas on the NZPCN website do relate to invasive plants: • exotic plant search results (www.nzpcn.org.nz/flora/species/?native=0): exotic taxon profiles include 'Year naturalised', 'Origin', 'Reason for introduction' and other headings related to invasiveness • NZ Naturalised Vascular Plant Checklist (www.nzpcn.org.nz/publications/documents/nz-naturalised-vascular-plant-checklist) • Threats: Exotic Plants (www.nzpcn.org.nz/threats/exotic-plants).
Primary contact(s)	**Name(s)**	Bill Campbell (Administrative Officer)

	Email	info@nzpcn.org.nz
Access	**Web**	Home page: www.nzpcn.org.nz
	Publications	• NZPCN Strategy 2018–2022 (www.nzpcn.org.nz/publications/documents/nzpcn-strategy-2018) • *Trilepidea*, the NZPCN newsletter (www.nzpcn.org.nz/publications/documents/?publication_type=6148) • national plant checklists (www.nzpcn.org.nz/publications/plant-lists/national-plant-lists/)
User base	>800 paid members. Members include DOC, botanists, NGOs, research institutes such as universities, private businesses, botanic gardens, schools, central and local government employees, members of the public, ecological restoration programmes, and private landowners. One of the few membership models that successfully attract younger members. The average monthly sessions for 2019 were 30,750.	
Relationship to other resources	Based on monthly website sessions it has more than seven times the user base than the similar species descriptions housed on the nzflora website (www.nzflora.info). Species profiles on the NZPCN website are consistently ranked higher in Google searches than similar nzflora profiles. Where based upon the original printed floras, NZPCN species profiles (both native and exotic) closely match and overlap with those of MWLR's nzflora (Flora of New Zealand Online). Gaps in species descriptions are also closely mirrored in both resources. The NZPCN native species descriptions written by Peter de Lange, as part of his broader research, are more comprehensive than those in MWLR's nzflora. Both NZPCN and MWLR publish indigenous and naturalised plant lists. The NZPCN and MWLR resources do not actively interconnect, which has created duplication of effort. NZPCN species profiles have (inconsistent) links for: • iNaturalist NZ observations for that species (newly added) • Museum of New Zealand – Te Papa Tongarewa herbarium specimens (but not the Allan Herbarium, Auckland War Memorial Museum, National Forestry Herbarium – or the overarching Australasian Virtual Herbarium) • Flora of New Zealand descriptions (digitised versions of the original printed floras at https://floraseries.landcareresearch.co.nz/pages/Index.aspx, rather than the more useful nzflora pages at www.nzflora.info). Following the April 2020 NZPCN website rebuild, two features have been	

	discontinued:
	
	• plant distribution data, drawing from snapshot datasets of:
	  ○ DOC's plant database
	  ○ national plant checklist database (developed by Graeme Jane)
	  ○ MWLR National Vegetation Survey Database (NVS) data
	  ○ NZPCN distribution database, including phenology data
	• 'Record your observations', similar to iNaturalist NZ.
	
	Discontinuation of these features is a good decision, because it means that the community is no longer divided between competing/overlapping resources. Plant distribution and recording on the NZPCN platform were innovative at the time, but have now been overshadowed by enhancements to NVS, GBIF, and iNaturalist.

Summary	An extensive independent resource with a clear focus. The web platform was recently redeveloped and is easy to use. Popular resources with a wide and loyal user base of conservationists. The majority of work is done by volunteers, who are responsive to user feedback. It overlaps, and could be said to compete, with species descriptions on the nzflora website (www.nzflora.info).

Name of database/resource	Manaaki Whenua – Landcare Research (MWLR): online key to the weed species of New Zealand			
Purpose/rationale	To provide rapid and accurate identification of NZ weed species. Began as an identification tool for National Pest Plant Accord (NPPA) species and expanded to include other categories of weeds.			
Development and maintenance	**Development timeline**	• 2007–2009: key to NPPA species • 2011: DOC Environmental Weeds added • 2012: new NPPA species added • 2014–2016: Regional Pest Management Plan (RPMP) and common weed species added • 2018: major update to Lucid interactive key platform • 2019: botanical names, links, images updated		
	Developer	Murray Dawson, MWLR		
	Maintainer	Murray Dawson, MWLR		
	Update frequency	As required and subject to available funding.		
	Status	Active ☒	Dormant☐	Terminated☐
	Main contributors	Peter Heenan (MWLR) and Paul Champion (NIWA) contributed to the initial design; Sheldon Navie (Technigro) provided images and character state scores based on a similar Australian key; Trevor James (AgResearch) contributed his extensive image collection of weeds. Other contributors are listed at: • www.landcareresearch.co.nz/resources/identification/plants/weeds-key/acknowledgements • www.landcareresearch.co.nz/resources/identification/plants/weeds-key/images		
	Development costs	The now defunct TFBIS (Terrestrial & Freshwater Biodiversity Information System) Programme funded most of the project development (with three grants from 2007 to 2016). MPI has provided modest support to update the NPPA		

		species as required (2012 & 2019). Some discretionary MWLR funds have been provided. In total, more than $440,000 has been invested in this resource. Lucid interactive keys are time-consuming to produce (currently estimated at $1,000–1,700+ per species).		
	Ongoing resourcing / maintenance costs	Further development is contingent on attracting new funding. Although adding new species is relatively expensive, ongoing maintenance costs are negligible because Lucid builder software allows for easy updating and MWLR hosts the key on its comprehensive website.		
Data content	**Data type**	Author authorities ☐	Extensive synonymy ☐	Mapping/ geodata ☐
	Data/information quality	• Up-to-date botanical names • Common synonyms are used • Common names are used • Comprehensive image sets for species and character states • Accurate and extensive character scoring to ensure reliable identification.		

	Overall scope/coverage	• 667 taxa
		• Several categories of invasive plants:
		  ○ common weeds
		  ○ DOC Environmental Weeds
		  ○ National Pest Plant Accord species
		  ○ Regional Pest Management Plan species
		  ○ non-weed look-alikes.
		• Identification through 49 characters and 228 character states (e.g. plant form, leaf, floral, fruit and seed characteristics)
		• 11,000 images.		

	Data/information strengths	• A comprehensive online tool dedicated to identifying NZ weeds. • A powerful interactive identification and teaching tool. • Fully featured with explanations of characters, extensive images, and links to related resources. • Uses botanical descriptions from published floras for character scores.		

		• Main synonyms and common names are included. • Plant names align with the Ngā Tipu o Aotearoa – New Zealand Plants database and NZOR. • Architecture and character state scoring are robust and consistent with an equivalent Lucid key in Australia.
	Data/information weaknesses	• No dynamic (active) connections to related databases. • Earlier versions were difficult to run for some users (due to Java runtime environment issues); this has been resolved since 2018. • Not currently aligned with new RPMPs. • Browser-based only; no smartphone versions. • Different technology from image recognition; relies on the user learning how to use the tool to identify plants.
	Data/information gaps	Many common weed species are missing from the tool due to its history of development and funding objectives.
	Invasive plant relevance	The sole focus of this tool is accurate identification of different categories of invasive plants.
Primary contact(s)	**Name(s)**	Murray Dawson
	Email	dawsonm@landcareresearch.co.nz
Access	**Web**	www.landcareresearch.co.nz/resources/identification/plants/weeds-key
	Publications	Publicising the key: • Dawson & Wilson-Davey (2011) • Dawson (2011) • Dawson (2014) • Dawson (2016).
User base	• The most popular Lucid key hosted by MWLR. • Regular email feedback received from users of the key. • Wide user base, including weed experts, researchers, MPI, regional councils, farm consultants, and the general public. • Used as the primary identification tool for MPI-led NPPA training delivered to regional council plant pest officers.	

Relationship to other resources	Draws heavily on Trevor James's extensive image collection of weeds, shared with Weedbusters NZ (www.weedbusters.org.nz), AgPest (https://agpest.co.nz), *An Illustrated Guide to Common Weeds of New Zealand* (Popay et al. 2010), the National Pest Plant Accord (NPPA), regional council pest management publications, and other invasive plant resources. Links within the key to species profiles and related resources: • Ngā Tipu o Aotearoa – New Zealand Plants database (PND): https://nzflora.landcareresearch.co.nz • nzflora weed profiles: www.nzflora.info/browse.html • Weedbusters NZ: www.weedbusters.org.nz • NPPA: www.mpi.govt.nz/protection-and-response/long-term-pest-management/national-pest-plant-accord • AgPest: https://agpest.co.nz. Part of a suite of 10 other Lucid plant identification keys hosted by MWLR: those that also include naturalised/invasive plants of NZ are: • key to flowering plant genera of NZ: www.landcareresearch.co.nz/resources/identification/plants/flowering-plants-key • NZ Grass Key – key to the grasses of NZ: www.landcareresearch.co.nz/resources/identification/plants/grass-key • key to *Cotoneaster* species present in NZ: www.landcareresearch.co.nz/resources/identification/plants/cotoneaster-key • key to willow species and hybrids present in NZ: www.landcareresearch.co.nz/resources/identification/plants/salix-key • key to Myrtaceae species of NZ: https://keys.landcareresearch.co.nz/nzmyrtaceae/ (currently as a test version). Closely related to the LucidMobile 'Environmental Weeds of Australia' smartphone app: • Android: https://play.google.com/store/apps/details?id=org.lucidcentral.mobile.ewa&hl=en • iOS: https://apps.apple.com/pl/app/environmental-weeds-of-australia/id898685476
Summary	A powerful and fully featured interactive identification key to NZ weed species. A good teaching tool, but with a moderate learning curve that can be off-putting to casual users. Would benefit from the addition of more common weeds, and from smartphone renderings.

Name of database/resource	New Zealand Plant Protection Society Inc. (NZPPS): *An Illustrated Guide to Common Weeds of New Zealand* [book]			
Purpose/rationale	To provide a comprehensive and easy-to-use guidebook to common weeds species of NZ.			
Development and maintenance	**Development timeline**	• 1998: 1st edition • 2004: 2nd edition • 2010: 3rd edition • 2021: expected publication of 4th edition		
	Developer	Published by the NZPPS.		
	Maintainer	n/a		
	Update frequency	Three editions have been published at 6-year intervals. Each edition has grown to include more weed species. Production of a fourth edition will be digitally printed, allowing for smaller, more economical print runs. The publishers are also likely to make content available online, as an e-book at https://nzpps.org.		
	Status	Active ☐	Dormant☒	Terminated☐
	Main contributors	NZPPS have supported the production of these books. Paul Champion, Trevor James and the late Ian Popay are authors of the current edition. Authors of earlier editions include Bruce Roy and Anis Rahman. Fiona and Rob Richardson of Victoria, Australia, have been responsible for the design and editing of the book – they are also weed experts in their own right.		
	Development costs	The majority of work producing editions of this book has been done as a 'labour of love', largely outside the scope of CRI research programmes. However the photo collection has been accumulated through about 50:50 AgResearch and Trevor James's personal time. NZPPS cover all publishing and printing costs and retain all profits from sales. There has been no other supporting funds		

		for this book.		
	Ongoing resourcing / maintenance costs	As above for development costs. The NZPPS agreed to publish the fourth edition, and the authors of the new edition will devote personal time to the project.		
Data content	**Data type**	Author authorities ☐	Extensive synonymy ☐	Mapping/ geodata ☐
	Data/information quality	• Botanical names are checked with botanists to ensure their accuracy for each edition, and are in concordance with those followed in the Landcare Research Ngā Tipu o Aotearoa – New Zealand Plants database (http://nzflora.landcareresearch.co.nz). • Each botanical name is usually followed by one common name and sometimes also by a main synonym (a previous botanical name by which the plant was known). • Text is succinct and largely accurate. • Images are high quality and carefully chosen.		
	Overall scope/coverage	For the current (2010) edition: • 416 pages • 388 taxa, with a further 230 related or similar species mentioned, most also with photographs. • >2,100 images.		

	Data/information strengths	• Botanical names are current at the time of each printing.
		• Excellent layout and content well pitched for the target audience.
		• Plants are arranged according to four groups:
		  ○ plants with spores (ferns and fern-like plants)
		  ○ plants with cones (conifers)
		  ○ flowering plants (dicotyledons – the majority covered)
		  ○ flowering plants (monocotyledons).
		• The text is succinct and largely accurate for each weed profiled, and includes:
		  ○ brief weed description in bold
		  ○ features such as flowers, fruit, leaves, stems, roots
		  ○ notes on habitat, distribution, derivation of botanical name, and related or similar species.		

		• High-quality and carefully chosen images are used; the great majority were photographed by Trevor James.
	Data/information weaknesses	Although excellent in its function as a guidebook, it can be difficult to quickly identify invasive plants compared to some online solutions. The 'Guide to flower colour and size' (pp. xviii–xxvi) is a useful colour-coded reference that helps broadly identify a plant from information about flower colour and size, the kind of plant it is and the habitat it occupies. A few minor description errors have propagated across from the underpinning *Flora of New Zealand* series (e.g. Webb et al. 1988), and the derived Flora of New Zealand Online (www.nzflora.info), which have not corrected the original descriptions.
	Data/information gaps	Grasses, sedges and rushes are acknowledged not to be covered in detail in the main body of the book. However, these are extensively treated in a companion guidebook, *An Illustrated Guide to Common Grasses, Sedges and Rushes of New Zealand* (Champion et al. 2012). *Pinus contorta* has its own profile, but given the current issues with wilding conifers it would be useful to have other wilding species with their own profiles.
	Invasive plant relevance	The authors have aimed to include all common weeds, comprising garden escapes, naturalised plants and some native species that can become weedy.
Primary contact(s)	**Name(s)**	Trevor James
	Email	trevor.james@agresearch.co.nz
Access	**Web**	https://nzpps.org/book/an-illustrated-guide-to-common-weeds-of-new-zealand-third-edition
	Publications	Book review by Murray Dawson: www.rnzih.org.nz/RNZIH_Journal/Pages_31-36_from_2010_Vol13_No1.pdf.
User base	Plant pest managers, farmers, students, gardeners, and anyone else working in areas or	

	industries affected by weeds. About 10,000 copies have been sold across all editions, with almost 4.000 copies sold of the current (third) edition. Sales have decreased dramatically following the demise of Manaaki Whenua Press as a bookseller in December 2013 (when it was their biggest seller) and Touchwood Books, which ceased operating on 31 July 2019. The current agents are Nationwide Book Distributors.
Relationship to other resources	This book effectively replaces some earlier titles that are out of print, including: • *Weeds of New Zealand and How to Eradicate Them* (Hilgendorf 1926) • *Common Weeds in New Zealand: An illustrated guide to their identification* (Parham and Healy 1976) • *Identification of Weeds and Clovers* (Healy 1976) • *The New Zealand Garden Weed Book. A guide to identification and control* (Ivens and Taylor 1985); and perhaps • *A Guide to the Identification of New Zealand Common Weeds in Colour* (Upritchard 1997), which is still in print but now very dated. Names used in this book are checked against those in Ngä Tipu o Aotearoa – New Zealand Plants database (http://nzflora.landcareresearch.co.nz). Most images used in this book were photographed by author Trevor James, who has shared his extensive image collection with other resources such as the MWLR online key to the weed species of NZ (www.landcareresearch.co.nz/resources/identification/plants/weeds-key), Weedbusters NZ (www.weedbusters.org.nz), AgPest (https://agpest.co.nz), the National Pest Plant Accord (NPPA), and regional council pest management publications. *An Illustrated Guide to Common Weeds of New Zealand* could be considered a companion book to *An Illustrated Guide to Common Grasses, Sedges and Rushes of New Zealand* (Champion et al. 2012) and *An Illustrated Guide to Weed Seeds of New Zealand* (James et al. 2012).
Summary	Editions of this guide are the standard popular reference for information on NZ's weed species. A user-friendly, comprehensive and practical guide, highly regarded by users. For the next edition, NZPPS has agreed to printing smaller runs using a desktop publishing company.

Name of database/resource	Ministry for Primary Industries (MPI): Biosecurity New Zealand: National Pest Plant Accord (NPPA)			
Purpose/rationale	The National Pest Plant Accord (NPPA) is an agreement to prevent the sale, distribution and propagation of specified pest plants where either formal or casual horticultural trade is the most significant way of spreading the plant in NZ.			
Development and maintenance	**Development timeline**	• 2001: the Accord came into effect, initially between regional councils and government departments with biosecurity responsibilities (i.e. Ministry of Agriculture and Forestry and DOC). • 2006: the Accord was revised to include the then Nursery and Garden Industry Association (NGIA) as a member of the decision-making body. The successor industry organisation is New Zealand Plant Producers Incorporated (NZPPI). • 2007: three additional species were added to the Accord list. • 2008: six additional species were added to the Accord list. • 2012: 13 additional species were added to the Accord list. • 2020: minor amendments were made to the plant identification booklet relating to the Accord list.		
	Developer	Biosecurity New Zealand		
	Maintainer	Biosecurity New Zealand		
	Update frequency	The intent was to review the Accord list every 5 years. The last major review was held in 2012, and no species have been added (or removed) since then; later dates on the booklet reflect reprints and minor amendments only. Biosecurity New Zealand intends to initiate the next review of the Accord list in 2021.		
	Status	Active ☒	Dormant☐	Terminated☐
	Main contributors	Anyone interested can suggest a change to the Accord list by filling out a proposal form. An NPPA Technical Advisory Group (TAG) carries out risk assessments and makes recommendations to the NPPA		

		Steering Group on amending the Accord list. Members of the public and stakeholders have the opportunity to view and comment on the TAG's assessment and recommendation. The NPPA Steering Group (comprising representatives from the NZPPI, councils, Biosecurity New Zealand and DOC) agree to the final amendments to the Accord list. Any species that are not currently declared Unwanted Organisms under the Biosecurity Act are submitted to the MPI Chief Technical Officer for consideration and a decision on their Unwanted Organism determination. To be included on the Accord list the pest plant must be an Unwanted Organism. Regional council staff are trained and appointed as NPPA authorised persons under the Biosecurity Act. They carry out surveillance and inspection activities to ensure the pest plants are not being sold, propagated or distributed.		
	Development costs	Not supplied.		
	Ongoing resourcing / maintenance costs	Reviewing the Accord list is resource intensive: it involves significant administration and bringing together the Technical Advisory Group and Steering Group. The Biosecurity New Zealand NPPA coordinator role is approximately 0.3 FTE. Councils provide sufficient NPPA authorised persons to carry out surveillance and inspection activities; Biosecurity New Zealand provides training for authorised persons.		
Data content	**Data type**	Author authorities ☐	Extensive synonymy ☐	Mapping/ geodata ☐
	Data/information quality	• Botanical names are checked with botanists to ensure their accuracy for each edition of the Accord, and are in concordance with those followed in Ngā Tipu o Aotearoa – New Zealand Plants database (http://nzflora.landcareresearch.co.nz). • Scientific and common names are included. • The text is brief and largely accurate. • Images are mostly well chosen.		

	Overall scope/coverage	The list has expanded significantly over the years. The current (2020) print edition includes: • 163 Accord species banned from propagation, sale, and distribution within NZ • 234 images • 148 pages.

	Data/information strengths	• Botanical names are current at the time of each printing.
		• Layout is excellent considering the size limitations of the spiral-bound booklet.
		• Plants are arranged alphabetically by botanical name, with an index of common and also botanical names.
		• The text is brief and largely accurate for each NPPA species profiled, with headings that include:
		  ○ other common names
		  ○ synonym
		  ○ description
		  ○ impact
		  ○ what to do.
		• A good selection of images, with many provided by invasive plant experts.

	Data/information weaknesses	The booklet is a useful and portable reference to highlight NPPA species, but the content is limited for identifications. Because the Accord is an agreement involving different sectors and opinions, the resultant species list reflects this: it includes species that are of most concern to the different Accord parties. There is some misperception that the Accord list is a national weeds list. The Accord is not designed as the sole means of controlling weeds, and is not intended for plants that haven't been sold through the trade. There are a few minor errors despite the recent revision.
	Data/information gaps	Due to the submission and agreement process there are some apparent inconsistencies and omissions, whereby some weeds (including DOC Environmental Weeds and/or Regional Pest Management Strategy species) are cultivated and not banned from propagation, distribution and sale. For example, these include: • several *Cotoneaster* species (other than *C. simonsii*,

		which is a listed NPPA species) • *Crocosmia* ×*crocosmiiflora* (montbretia) • *Eschscholzia californica* (Californian poppy) • *Hedera* (ivy) • *Paraserianthes lophantha* (brush wattle) • *Prunus* spp. (other than *P. serotina*, which is a listed NPPA species) • *Vinca major* (periwinkle).
	Invasive plant relevance	All plants on the Accord list are unwanted organisms under the Biosecurity Act 1993. However, the MPI Unwanted Organisms Register does not retrieve all NPPA species when choosing "plant" and "unwanted".
Primary contact(s)	**Name(s)**	John Sanson (NPPA Steering Group Chair) Kate Brown (NPPA Co-ordinator)
	Email	John.Sanson@mpi.govt.nz Kate.Brown@mpi.govt.nz
Access	**Web**	www.biosecurity.govt.nz/protection-and-response/long-term-pest-management/national-pest-plant-accord
	Publications	The NPPA manual is available free as a PDF and as a spiral-bound booklet (MPI 2020).
User base	DOC, regional councils, plant production nurseries, horticulturists. 584 sessions per month for the main NPPA page (1 May 2019 – 1 May 2020).	
Relationship to other resources	• iNaturalist NZ includes a checklist of NPPA species: (https://inaturalist.nz/check_lists/176323-National-Pest-Plant-Accord-species) • Names used in the NPPA are checked against those in Ngā Tipu o Aotearoa – New Zealand Plants database (http://nzflora.landcareresearch.co.nz). • Many images used in the NPPA manual were photographed by Trevor James, who has shared his extensive image collection with other resources such as the book *An Illustrated Guide to Common Weeds of New Zealand*; the MWLR online key to the weed species of NZ (www.landcareresearch.co.nz/resources/identification/plants/weeds-key); Weedbusters NZ (www.weedbusters.org.nz); AgPest (https://agpest.co.nz); and regional council pest management publications. • Regional council staff who are appointed NPPA-authorised persons receive	

	training on the MWLR online key to the weed species of NZ (www.landcareresearch.co.nz/resources/identification/plants/weeds-key) for the purposes of identifying NPPA species.
Summary	Banning invasive plants from propagation, sale, and distribution is a sound concept, and the initiative is successful. There has been very good cooperation between government departments and the plant production industry. The Accord list is overdue for an update; it is Biosecurity New Zealand's intention to initiate a review of the list in 2021.

Name of database/resource	Weedbusters NZ: website and resources			
Purpose/rationale	An advocacy and outreach resource to encourage communities (including plant restoration groups, schools and the public) to work together (in partnership with local government, central government, and research organisations) for the active control of weeds, and to promote education about invasive plants.			
Development and maintenance	**Development timeline**	• 1994: the Weedbusters concept began as a Weed Awareness Week held each year in Queensland. This subsequently expanded to other Australian states. • 2003: Weedbusters NZ was established as an inter-agency programme, led by DOC with the support of regional councils.		
	Developer	DOC and regional councils provided funds to develop these resources. Continued development is led by a national coordinator (funded by DOC), and supported by an informal network of contributors. The database-driven website was created by two self-employed developers: Tony Stoddard created the original Weedbusters NZ site in 2003, and Robin Sallis rebuilt it in 2015.		
	Maintainer	Content is maintained, and outreach championed, by the national coordinator. For 15 years this key role was filled by Carolyn Lewis, who has been the driving force behind Weedbusters NZ. The national coordinator contract funded by DOC ceased in December 2019, and maintenance is currently limited to periodic website updates (until June 2020).		
	Update frequency	Community group weed control and native planting events are constantly changing and regularly updated on the Weedbusters NZ website. Other content is updated as required. The associated Facebook page has an average of several posts each month and is relatively current.		
	Status	Active ☒	Dormant☐	Terminated☐

	Main contributors	Carolyn Lewis has been the main contributor. Other contributors are from: • community groups • regional councils / unitary authorities • CRIs (e.g. Trevor James, AgResearch; Murray Dawson, MWLR; Paul Champion, NIWA). Supporting organisations are listed at: www.weedbusters.org.nz/weedbusters-nz/supporters		
	Development costs	Development of the Weedbusters NZ programme is ongoing. The overall budget was about $100,000 a year, which includes the national coordinator's and web developer's time.		
	Ongoing resourcing / maintenance costs	The national coordinator role has been 20 hours per week, and is contracted out by DOC. This essential 'one-person' role delivers regular and effective outreach, communication and advocacy to keep the goals of the Weedbusters NZ programme alive. Regional councils cover costs for printing of the Plant Me Instead regional booklets relevant to their areas.		
Data content	**Data type**	Plant author authorities ☐	Extensive name synonymy ☐	Mapping/ geodata ☐
	Data/information quality	The website and associated content are accurate. Feedback is responded to and implemented promptly.		

	Overall scope/coverage	• 225 invasive plants are listed by common name and profiled.
		• There are many other associated pages and much media-ready content.
		• There is a network of 327 Weedbusters NZ groups from 14 regions:
		  ○ Northland (25 groups)
		  ○ Auckland (60 groups)
		  ○ Bay of Plenty (19 groups)
		  ○ Waikato (42 groups)
		  ○ East Coast–Hawke's Bay (11 groups)
		  ○ Taranaki (6 groups)
		  ○ Wanganui–Manawatu (15 groups)
		  ○ Wellington (45 groups)
		  ○ Nelson–Tasman (18 groups)		

		○ Marlborough (7 groups) ○ West Coast (6 groups) ○ Canterbury (46 groups) ○ Otago (18 groups) ○ Southland (9 groups).
	Data/information strengths	Information throughout is user-friendly and well-tailored to the intended audience; content is not over-technical. The species profiled have been chosen to include a useful range of environmental weeds. The ability to download the online profiles as print-friendly PDF information sheets is a helpful feature.
	Data/information weaknesses	Species profiles linking from the weed list (www.weedbusters.org.nz/weed-information/weed-list) are browsable by common name (which is appropriate for most users) but not by botanical name. However, profiles are retrievable through botanical names (for more expert users) using a search box that is also provided. Images in the weed profiles do not have consistent captions naming the contributing photographers (this is currently being addressed), or stated Creative Commons licensing.
	Data/information gaps	• There is scope to add further weed profiles if future resourcing allows. • A few species profiles lack images. This gap has progressively been filled in recent years, and Trevor James (AgResearch) recently contributed his extensive image collection to Weedbusters NZ. • Further links to external resources, such as those for weed identification, would be useful (e.g. the *Common Weeds of New Zealand* book and the MWLR online key to weeds of NZ).
	Invasive plant relevance	The sole focus of Weedbusters NZ is environmental weeds / invasive plants and how to manage them. As stated at www.weedbusters.org.nz/weed-information/what-are-weeds, 'Weedbusters is about the invasive plants which have a harmful impact on the wider natural environment, on our economy, and on human and animal health.' Advice for practical control of invasive plants is comprehensive and very useful.

Primary contact(s)	**Name(s)**	National coordinator
	Email	info@weedbusters.org.nz
Access	**Web**	• www.weedbusters.org.nz • www.facebook.com/weedbustersnz
	Publications	A range of booklets and pamphlets, many of which are free to community groups, including: • *Weedbusting Guide* • Plant Me Instead booklets (by region) • *Weed Control Handbook*.
User base	An average of 20,000 website sessions per month for 2019. An extensive network of community groups, regional councils and others involved in plant pest control. Links to Weedbusters NZ pages are regularly posted on various Facebook weed group pages. The associated Facebook page currently has >500 followers.	
Relationship to other resources	Content on the Weedbusters NZ website is relatively original and stand-alone, with no interconnected databases. Some of Trevor James's weed images used on the Weedbusters NZ website are shared with other resources, such as the MWLR online key to the weed species of NZ (www.landcareresearch.co.nz/resources/identification/plants/weeds-key), AgPest (https://agpest.co.nz), *An Illustrated Guide to Common Weeds of New Zealand* (Popay et al. 2010), the National Pest Plant Accord (NPPA), and regional council pest management publications. There is an iNaturalist NZ widget at www.weedbusters.org.nz/get-involved, providing a feed from the Pest Plants (weeds) of NZ project at https://inaturalist.nz/projects/pest-plants-weeds-of-nz	
Summary	A successful programme focused on environmental weeds, outreach, and providing practical resources to the community. A well-presented, user-friendly, database-driven website. The contract for the national coordinator role expired December 2019. Renewal of this key role is needed to ensure ongoing resourcing and continuity.	

Name of database/resource	AgResearch: AgPest website (formerly PestWeb)			
Purpose/rationale	'AgPest offers a single website that includes practical information to upskill farmers and their advisors on identification and management of over 80 pests and weeds and provides alerts emailed out to registered users. These alerts provide timely information warning farmers of pest issues in their region and suggest appropriate management responses.' (http://agpest.co.nz/about-us)			
Development and maintenance	**Development timeline**	• 2008: PestWeb website was created • 2015: re-branded AgPest • 2016: 11 new species added • 2016–2020: 5 new weeds added per year		
	Developer	Development has been led by Katherine Tozer, with contributions from other staff (including Colin Ferguson and Trevor James) from AgResearch.		
	Maintainer	Katherine Tozer.		
	Update frequency	Maintained as required with major updates contingent on external funding. Frequency of posts on the associated Facebook page are about once a month, and it is relatively current.		
	Status	Active ☒	Dormant☐	Terminated☐
	Main contributors	AgResearch staff are the main contributors. Paul Champion (NIWA) and Research Associate the late Ian Popay have also been major contributors to the weed profiles. Funding has been provided by AgResearch, Beef + Lamb, Dairy NZ, MPI (under the old Sustainable Farming Fund), and the New Zealand Plant Protection Society.		
	Development costs	>$200,000		
	Ongoing resourcing / maintenance costs	Weed and pest species are added as and when funding becomes available ($10,000 per year on average).		
Data content	**Data type**	Plant author	Extensive name	Mapping/

		authorities ☐	synonymy ☐	geodata ☐
	Data/information quality	Website and associated content are accurate.		
	Overall scope/coverage	• 86 pasture weed entries containing >143 species • (33 plant pest insect entries)		
	Data/information strengths	Pasture weeds and pests have been chosen in consultation with key farming, industry and research personnel. Complete and high-quality information is provided for a carefully chosen range of pasture weeds and insect pests. Each species profile has an image gallery and tabs with bullet-pointed information under the categories: • key characteristics • biology • impacts • control • further information. The print-friendly and PDF output of these profiles render well. The AgPest website includes other useful information, such as a concise list of links to related resources.		
	Data/information weaknesses	The identification tool is relatively weak (but easy to use) compared with other solutions. Images in the weed profiles lack photographer credits (all were taken by Trevor James) and Creative Commons licensing (the whole site is copyrighted).		
	Data/information gaps	A stated objective is to add further species. This will be dependent on successful funding applications.		
	Invasive plant relevance	The focus is on pasture weeds (and plant pests), all of which are invasive.		
Primary contact(s)	**Name(s)**	Katherine Tozer		
	Email	agpest@agresearch.co.nz		

Access	**Web**	• https://agpest.co.nz • www.facebook.com/agpestnz • https://twitter.com/AgPestNZ
	Publications	n/a
User base	The AgPest resources are aimed at arable pasture farmers. There is an average of 6,000 sessions per month at https://agpest.co.nz. The website has a 'Get Alerts' option to join a mailing and text alert list; this mailing list currently has 69 subscribers. The associated Facebook page currently has >260 followers and the Twitter feed has 580 followers.	
Relationship to other resources	This database-driven website is stand-alone, and does not interconnect with other databases. Some of Trevor James's weed images used here are shared with *An Illustrated Guide to Common Weeds of New Zealand* (Popay et al. 2010), Weedbusters NZ (www.weedbusters.org.nz), the NPPA booklet, the MWLR online key to the weed species of NZ (www.landcareresearch.co.nz/resources/identification/plants/weeds-key), and regional council pest management publications.	
Summary	A clean, well-constructed, and easy-to-use database-driven website that focuses on a select list of pasture weeds and insect pests. Overall a very good implementation.	

Name of database/resource	Massey University: New Zealand Weeds Database			
Purpose/rationale	As stated on their home page, this resource is 'dedicated to informing people about weeds in New Zealand. It has been designed both for members of the public and for students studying weeds.' The weed profiles were created to complement weed courses taught at Massey University, including 'Understanding Herbicides' and 'Controlling Weeds'.			
Development and maintenance	**Development timeline**	This resource was first available as webpages in the late 1980s.		
	Developer	Kerry Harrington		
	Maintainer	Kerry Harrington and the Massey University web content manager		
	Update frequency	Pages are updated once a year, which often involves updating external links.		
	Status	Active ☒	Dormant☐	Terminated☐
	Main contributors	Kerry Harrington		
	Development costs	Numerous hours spent over many years creating the weed profiles, as part of developing teaching resources at Massey University. As such, it is not possible to cost out.		
	Ongoing resourcing / maintenance costs	The focus is on keeping existing weed profiles up to date rather than creating new profiles. New profiles are added based on new research. Minimal ongoing maintenance costs for the website because this resource is hosted by the Massey University servers.		
Data content	**Data type**	Author authorities ☐	Extensive synonymy ☐	Mapping/ geodata ☐
	Data/information quality	Content of the weed profiles is accurate.		

	Overall scope/coverage	• 77 weeds are listed by common name and profiled. • 233 images.
	Data/information strengths	The text is well written and informative, based on first-hand knowledge and incorporating weed research undertaken for each species. There are useful links to related research. Detailed and practical advice is presented on control methods. Each profile is titled with botanical name and family name, and the text sits under three headings: • Overview • Distinguishing features • Control.
	Data/information weaknesses	Species profiles are listed by common name only, and there is no dedicated search box for botanical names. The images provided in the weed profiles are good, but they lack a modern image gallery (to provide larger versions), captions (instead of alt tags), photographer credits (all are taken by Kerry Harrington), and stated Creative Commons licensing (the Massey University website generically grants non-commercial use).
	Data/information gaps	There is scope to add further weed profiles, although the focus of this resource is to provide high-quality information on a select subset of weed species.
	Invasive plant relevance	Species have been chosen to represent many of the most common weeds that cause problems in pastures, crops, lawns and gardens.
Primary contact(s)	**Name(s)**	Kerry Harrington
	Email	K.Harrington@massey.ac.nz
Access	**Web**	www.massey.ac.nz/weeds
	Publications	Related publications by the developer are listed at www.massey.ac.nz/massey/expertise/profile.cfm?stref=180300

User base	The weeds sub-site is one of the most visited sites within the Massey University website system. Users include current and prospective students, weed researchers, and the general public.
Relationship to other resources	A stand-alone resource with original text and images and no interconnected databases. Within the weed profiles there are useful links out to other resources, with a research focus. The number of weed profiles is almost equal in scope to that of AgPest (https://agpest.co.nz).
Summary	A moderate-sized and useful set of weed profiles that combine Kerry Harrington's excellent writing style and in-depth knowledge of weed research. Massey University offers the only university course in NZ solely on weeds. Their 3-day course 'Understanding Herbicides', is open to members of the public and is being increasingly taken by regional council staff tasked with dealing with invasive weeds.

Name of database/resource	New Zealand Bio-Recording Network (NZBRN): iNaturalist NZ – Mātaki Taiao	
Purpose/rationale	The aims of the NZBRN are to: 1. increase knowledge, understanding, and appreciation of New Zealand's natural history 2. engage and assist New Zealanders in observing and recording biological information 3. develop and support online tools to assist individuals and groups to record, view, share and use biological information 4. collaborate with people and groups interested in bio-recording 5. promote and provide secure, open, and ethical sources of biological information for the public. iNaturalist NZ – Mātaki Taiao is the NZBRN's main product and part of a free and open-source global citizen science platform originally developed by the California Academy of Sciences for recording and identifying observations of species.	
Development and maintenance	**Development timeline**	• 2005: Artportalen, a Swedish nature observation system, was adapted for NZ and named NZBRN. • 2010–2012: an independent NZ-optimised fork of iNaturalist was created and named NatureWatch NZ; citizen science observations from NZBRN were migrated into the new platform. • 2014: NatureWatch NZ was integrated into and operated directly from within the global iNaturalist servers. • 2018: the NZ name changed from NatureWatch NZ to iNaturalist NZ – Mātaki Taiao, with a new domain (https://inaturalist.nz/).
	Developer	NZBRN were responsible for platform development up until 2014. They are a charitable trust who aim to increase New Zealanders' engagement with and knowledge of nature. The trustees are NZ ecologists and biodiversity IT professionals: Colin Meurk and Jerry Cooper (MWLR), Jon Sullivan (Lincoln University), and Stephen Pawson (Scion). The global platform was developed by the California Academy of Sciences and more recently also funded by the National Geographic Society. iNaturalist began as the Master's final project of Nate Agrin, Jessica Kline, and Ken-ichi Ueda at UC Berkeley's School of Information in 2008.
	Maintainer	The California Academy of Sciences and the National

		Geographic Society, USA.		
	Update frequency	Developer updates to the codebase are daily. Species observations are continuously added by a global community.		
	Status	Active ☒	Dormant☐	Terminated☐
	Main contributors	Current developers of the global platform include Ken-ichi Ueda, Scott Loarie, Patrick Leary and others contributing to the open-source codebase (see www.inaturalist.org/pages/about). See https://inaturalist.nz/people for the list of NZ taxonomic curators and the leader boards of observers.		
	Development costs	Independent NZ development was funded by TFBIS (2005–2012). The global iNaturalist platform cost several million dollars.		
	Ongoing resourcing / maintenance costs	Ongoing resourcing is provided by the California Academy of Sciences and the National Geographic Society, USA.		
Data content	**Data type**	Plant author authorities ☐	Extensive name synonymy ☒	Mapping/ geodata ☒
	Data/information quality	The iNaturalist platform has a system of data quality assessment, including 'casual', 'needs ID' and 'research grade'. 'Research grade' observations apply to wild/naturalised taxa that have accurate dates, georeferences, and images, and are identified to the species level or lower by at least 2 out of 3 community identifiers.		
	Overall scope/coverage	The running total at https://inaturalist.nz/observations shows: • >1,000,000 citizen science observations (>800,000 verified) • >18,000 species • >20,000 observers • >6,000 identifiers.		

		This is the NZ stats of a much larger global network.
	Data/information strengths	This platform has numerous strengths, including: • crowdsourced citizen science data from a large community • spreadsheet import/export • machine learning and community identifications • designated curators • multiple image upload • distribution maps • life stage annotations (e.g. flowers, fruit) • project creation and posts • inbuilt email system • web browser and smartphone versions • forum for feature requests, bug reports etc.
	Data/information weaknesses	• Learning curve that makes it difficult to upload observations for new users, especially through the browser interface. • Observations with poor (or no) images are difficult or impossible to identify with certainty. • Numerous observations are not marked as cultivated, when they should be. • Cultivated plant records are not treated as 'Research Grade' and are unnecessarily excluded from GBIF. • When a user deletes their account, all of their observations, along with identifications and comments from the community are no longer accessible.
	Data/information gaps	There is missing functionality for ecological monitoring of a given location/plot over time.
	Invasive plant relevance	Data for invasive plants can be explored in numerous ways; for example, to retrieve distributions (at any taxon level and geographical scale), and phenology (flowering and fruiting times). Checklists can be created, such as one for National Pest Plant Accord (NPPA) species. Projects can be created to raise awareness of invasive plants, such as: • the umbrella 'Weeds observed by New Zealand schools', which groups individual school projects

		created from MWLR outreach • 'Pest Plants (weeds) of NZ', a place to share observations of weeds in NZ • 'The Dirty Dozen' project, to promote a past DOC initiative • the 'Canterbury Mayten Hunt!', an example of a recent initiative to raise awareness of Chilean mayten (*Maytenus boaria*), which is listed as organism of interest in Canterbury's RPMP (2018–2038).
Primary contact(s)	**Name(s)**	Jon Sullivan
	Email	help@inaturalist.nz
Access	**Web**	• https://inaturalist.nz/ NZ node • https://www.facebook.com/inaturalistnz/ NZ Facebook page • https://www.inaturalist.org/ global
	Publications	Sullivan et al. 2019 and many others
User base	>16,000 verified NZ observers; >1,200,000 global users. The associated NZ Facebook page currently has >4,300 followers.	
Relationship to other resources	iNaturalist NZ – Mātaki Taiao is the NZ node of a global network; other nodes are listed at www.inaturalist.org/pages/network. Plant names are transitioning to Plants of the World Online as a taxonomic reference. Images can be added via Flickr and Facebook feeds. Species profiles are drawn from a Wikipedia feed. 'Research grade' observations are deposited on GBIF.	
Summary	An excellent and widely used global platform that is comprehensive and has many features. The NZ node is the largest citizen science platform in the country.	