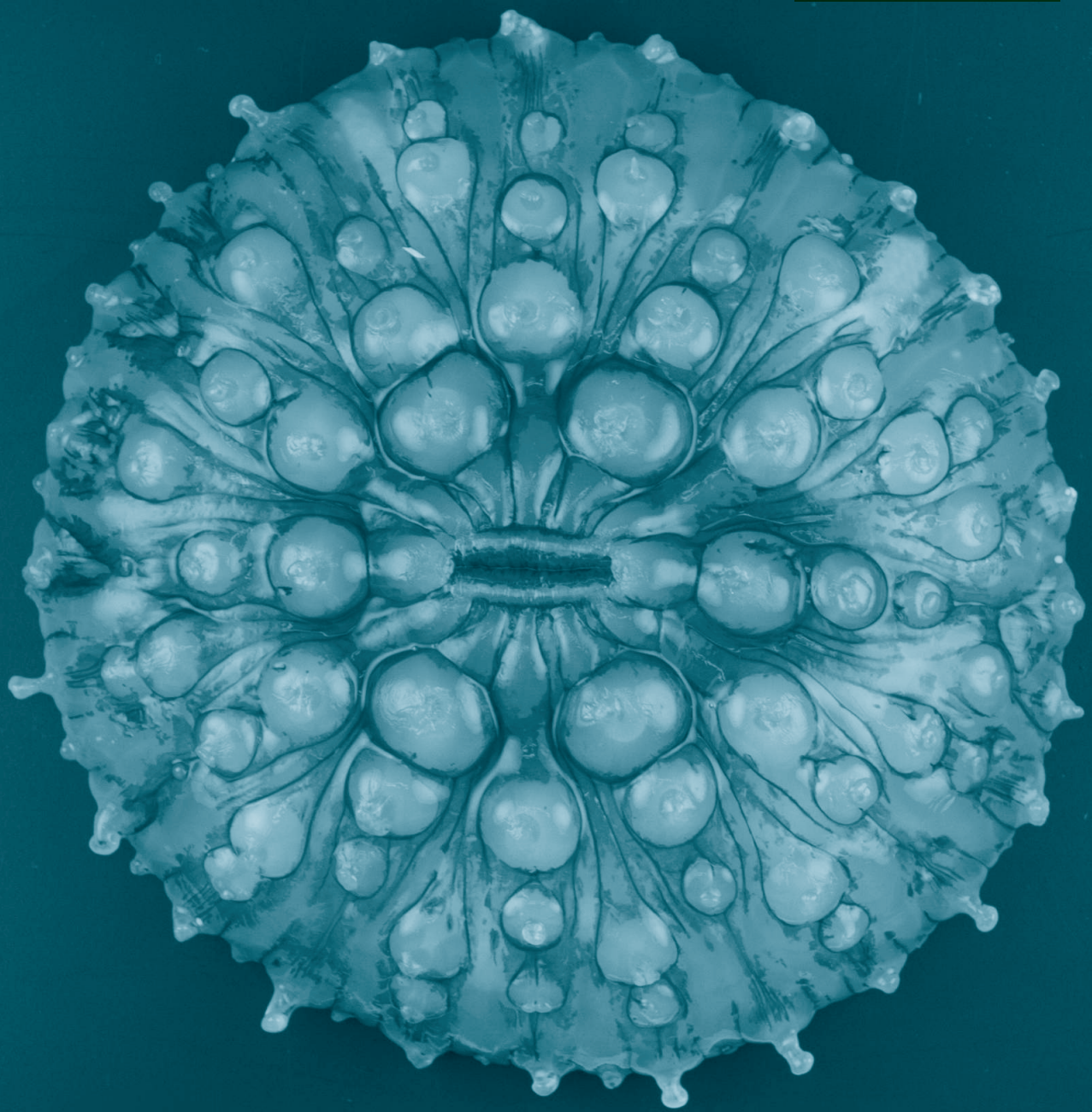
National Taxonomic Collections in New Zealand Appendices

December 2015

the ROYAL SOCIETY of NEW ZEALAND
TE APĀRANGI



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Appendix 1: Panel terms of reference

Terms of reference:

- Identify the significance of New Zealand's national taxonomic collections, and collections held internationally, that are of significance to New Zealand, in terms of:
    - identification, description, and classification of organisms
    - wider research in New Zealand
    - training of researchers
- Review the strategic guidance being provided over New Zealand's national taxonomic collections' directions, standards, and investment, to:
    - identify whether they are enabling the appropriate value to be gained from them, now and in the future
    - identify whether there are strategic approaches to defining primary and secondary collections and the need, or otherwise, for duplication
- Review the taxonomic training being undertaken in New Zealand, in terms of meeting New Zealand's needs.
- Provide recommendations on the funding and capacity of New Zealand's specialist taxonomic research and training.

Appendix 2: International conventions, and responsibilities of recognised institutions

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Taxonomy and nomenclature

The discipline of taxonomy is underpinned by a set of international conventions, duties, and responsibilities. The first formal attempt to bring order to the creation of names occurred in 1840 in zoology and 1867 in botany. The first truly international effort in zoology involved the establishment of the International Commission of Zoological Nomenclature in 1905. *The International Code of Zoological Nomenclature* (ICZN)[1] that was produced by this body has been revised four times. The most recent edition was published in 1999. *The International Code of Botanical Nomenclature* (ICBN)[2] was first published in 1952 and is regularly revised following the six-yearly meetings of the International Botanical Congress. At the last meeting in 2011, the ICBN was changed to the International Code of Nomenclature for algae, fungi, and plants (ICN) that provides the set of rules and recommendations dealing with the formal names that are given to plants, fungi and a few other groups of organisms, all those "traditionally treated as algae, fungi, or plants".

These codes have the purpose of promoting stability and universality in scientific names and include "articles" that are to be followed strictly by those creating or modifying names and "recommendations" that are intended as guidelines that should be followed. The basic principles that are addressed in the codes are the rules about the application of names (priority, availability, synonymy), a code of ethics, the requirement that a "type" specimen be designated, and recommendation that types be deposited in a recognised institution dedicated to the maintenance of scientific collections.

Accepted names

Through the application of rules of priority the names of New Zealand's flora, fauna, and mycota may be discovered in the following two online resources.

- New Zealand Organisms Register (NZOR)[3]: NZOR provides a consensus opinion on the preferred name for an organism, any alternative scientific names (synonyms), common and Māori names, relevant literature, and the data provider's view on the documented presence/absence in New Zealand.

- World Register of Marine Species (WoRMS)[4] aims to provide an authoritative and comprehensive list of names of marine organisms, including information on synonymy. While highest priority goes to valid names, other names in use are included so that this register can serve as a guide to interpret taxonomic literature. The content of WoRMS is controlled by taxonomic experts, not by database managers. WoRMS has an editorial management system where each taxonomic group is represented by an expert who has the authority over the content, and is responsible for controlling the quality of the information.

Responsibilities of a recognised institution

The most important and broad-ranging natural history collections internationally are in large public museums, although other institutions, for example Crown Research Institutes (CRIs) in New Zealand, have

[1] http://www.iczn.org/iczn/index.jsp .
[2] http://ibot.sav.sk/icbn/main.htm .
[3] http://www.nzor.org.nz/.
[4] http://www.marinespecies.org/about.php.

also taken on the responsibility of housing biological specimens and type material. The International Association for Plant Taxonomy and the New York Botanical Garden jointly produce "Index Herbariorum"[5] which is a detailed directory of the public herbaria of the world and the staff members associated with them. It is part of the training of systematists to know the major repositories of specimens relevant to their taxon.

The duties and responsibilities of recognised institutions are driven by recommendations in the International Codes. For example, the ICZN, in recommendation 72F, details that institutions in which name-bearing types are deposited should:

1. ensure that all are clearly marked so that they will be unmistakably recognised as name-bearing types;
2. take all necessary steps for their safe preservation;
3. make them accessible for study;
4. publish lists of name-bearing types in its possession or custody; and
5. so far as possible, communicate information concerning name-bearing types when requested.

Recommendation 7A.1 of the ICBN states "It is strongly recommended that the material on which the name of a taxon is based, especially the holotype, be deposited in a public herbarium or other public collection with a policy of giving *bona fide* researchers access to deposited material, and that it be scrupulously conserved."

It is now normal practice to make specimen data available on the world wide web (for example, over a million specimens of the 11 herbaria of New Zealand's National Herbarium Network[6] are made available online through the New Zealand Virtual Herbarium, and The National Institute of Water and Atmospheric Research's (NIWA) holdings[7] are now available online).

Responsibilities of borrowers of material from recognised institutions

The responsibilities of borrowers are no less than those of recognised institutions. The duty to "scrupulously conserve" specimens is absolute. Permission to alter type material in any way must be sought from the institution housing the material that has been lent. In the case of students, the ultimate responsibility for conservation of the material borrowed lies with the supervisors and their institutions.

Institutions, and also the legislation of some countries, may oblige researchers to deposit the holotype, return material to the country from which the floral, fungal, or faunal element is derived, and obtain permission to retain material. In the case of New Zealand, the Protected Objects Act 1975, administered by the Ministry for Culture and Heritage, is relevant[8]. The intent of this Act is reflected in the borrowing conditions of collection holding institutions. For example, the National Institute of Water & Atmospheric Research (NIWA) only allows material to be loaned for scientific study to bona fide researchers, with a duty of care for specimens including:

1. Material must remain at the institution to which it is loaned and the loan may only be transferred to a third institution with prior consent of NIWA.
2. No specimens are to be subjected to dissection or any destructive analysis without permission. Where permission is granted, all parts are to be returned.
3. If type material is designated from material on loan from NIWA, registration numbers must be attached to the specimens and quoted with the descriptions. The holotype and half of the paratype series are (by law) to be deposited at the NIWA Invertebrate Collection.

[5] http://sciweb.nybg.org/science2/IndexHerbariorum.asp.
[6] http://www.virtualherbarium.org.nz .
[7] http://niwa.co.nz/services/free/invertebratecollection .
[8] http://www.mch.govt.nz/protected-objects/index.html .

Appendix 3: List of organisations and individuals consulted as part of the review

Individuals consulted

Dr Barbara Barratt, Principal Scientist, AgResearch
Dr Jessica Beever, Landcare Research
Dr Stanley Bellgard, Landcare Research
Dr Alan Beu, Principal Scientist, GNS Science
Dr Dan Blanchon, Curator, Herbarium, Unitec Institute of Technology
Ms Kate Boardman, Landcare Research
Ms Nicola Bolstridge, Landcare Research
Mr Samuel Brown, PhD Student, Entomological Society of New Zealand
Dr Patrick Brownsey, Research Fellow, Te Papa
Dr Peter Buchanan, Science Team Leader, Systematics, Landcare Research
Dr Thomas Buckley, Landcare Research
Dr Matt Buys, Curator, National Forestry Herbarium, New Zealand Forest Research Institute (Scion)
Ms Leonie Clunie, Landcare Research
Dr Rochelle Constantine, University of Auckland
Dr Jerry Cooper, Landcare Research
Dr Mark Costello, Associate Professor, Institute of Marine Science, Leigh Marine Laboratory, University of Auckland
Dr James Crampton, Paleontologist, GNS Science
Dr Trevor Crosby, Landcare Research
Dr Justine Daw, General Manager, Landcare Research
Mr Murray Dawson, Landcare Research
Dr Mike Dickison, Curator of Natural History, Whanganui Regional Museum
Mr John Dugdale, Research Associate, Landcare Research
Dr Clark Ehlers, Senior Advisor (New Organisms), Environmental Protection Agency
Dr Allan Fife, Landcare Research
Ms Kerry Ford, Landcare Research
Mr Neil Gallagher, Environmental Management Officer, Plants, Horizons Regional Council
Ms Sue Gibb, Landcare Research
Dr David Glenny, Landcare Research
Dr Dennis Gordon, NIWA
Dr Richard Gordon, CEO, Landcare Research
Mrs Grace Hall, Landcare Research
Dr Alexandra Hare, formerly Landcare Research
Dr Peter Heenan, Landcare Research
Professor Steven Higgins, Department of Botany, University of Otago
Dr Rod Hitchmough, Science Advisor, Department of Conservation
Dr Virginia Hope, Programme Leader, Health Programme, Institute of Environmental Science and Research Limited (ESR)
Dr Robert Hoare, Landcare Research
Dr Neville Hudson, Paleontology Collection, School of Environment, University of Auckland
Dr Graeme Inglis, NIWA
Dr Peter Johnston, Landcare Research
Dr Michelle Kelly, NIWA
Professor Dave Kelly FRSNZ, Department of Biological Sciences, University of Canterbury
Ms Mary Korver, Landcare Research
Dr Marie-Claude Larivière, Landcare Research
Dr Daniel Leduc, NIWA
Dr Richard Leschen, Landcare Research
Dr Janice Lord, Department of Botany, University of Otago

Mr John Marris, Curator, Entomology Research Collection, Bio-Protection Research Centre, Lincoln University
Dr Nicholas Martin, Honorary Fellow, Plant & Food Research
Dr Eric McKenzie, Landcare Research
Ms Sadie Mills, Collection Manager, NIWA Invertebrate Collection, NIWA
Dr Frank Molinia, Landcare Research
Mr Al Morrison, Deputy Commissioner, State Services Commission
Mr Tom Myers, Botanical Services Officer, Dunedin City Council
Mr Robert Morris, Director, Collections and Research, Otago Museum
Ms Linn Murphy, LINZ
Dr Helen Neil, President, New Zealand Marine Science Society
Ms Kate Neill, NIWA
Professor Richard Newcomb, Chief Scientist, Plant & Food Research
Dr Phil Novis, Landcare Research
Dr Mahajabeen Padamsee, Landcare Research
Ms Elsa Paderes, Landcare Research
Mr Duckchul Park, Landcare Research
Dr Pieter Pelser, Senior Lecturer in Plant Systematics and Curator, University of Canterbury
Dr Shaun Pennycook, Landcare Research
Ms Megan Petterson, Landcare Research
Ms Debbie Redmond, Landcare Research
Dr Geoff Read, NIWA
Ms Birgit Rhode, Landcare Research
Dr Lesley Rhodes, Senior Research Scientist, Cawthron Institute
Ms Sue Scheele, Landcare Research
Dr Franz-Rudolf Schnitzler, Research Associate, Landcare Research
Dr Ines Schönberger, Landcare Research
Dr Paul Scofield, Senior Curator Natural History, Canterbury Museum
Dr Jochen Schmidt, Chief Scientist Environmental Information, NIWA
Dr Rob Smissen, Landcare Research
Dr Catherine Smith, Otago University
Ms Stephanie Sopow, Forest Entomologist, Scion
Professor Hamish Spencer FRSNZ, Department of Zoology, University of Otago
Mr Nick Spencer, Landcare Research
Dr Margaret Stanley, Senior Lecturer, Centre for Biodiversity and Biosecurity, University of Auckland
Mr Adrienne Stanton, Landcare Research
Dr Jennifer Tate, Massey University
Ms Katarina Tawiri, Landcare Research
Mr Alan Tennyson, Vertebrate Curator, Te Papa
Dr Stephen Thorpe, Honorary Research Associate, University of Auckland
Ms Di Tracey, NIWA
Dr Cor Vink, Curator Natural History, Canterbury Museum
Mr Manfred von Tippelskirch, Biosecurity Officer, Environment Canterbury
Dr Giselle Walker, Volunteer, Dunedin Botanic Gardens
Dr Darren Ward, Landcare Research
Dr Bevan Weir, Landcare Research
Dr Carol West, Director, Terrestrial Ecosystems, Department of Conservation
Ms Paula Wilkie, Landcare Research
Dr Aaron Wilton, Landcare Research
Dr Cedric Woods, Biolists.com
Dr Zeng Zhao, Landcare Research
Dr Zhi-Qiang Zhang, Landcare Research

Organisations met or consulted with

Research Institutes
The Cawthron Institute
ESR (The Institute of Environmental Science and Research)
GNS Science
Landcare Research - Manaaki Whenua
NIWA (National Institute of Water and Atmospheric Research)
Scion

Tertiary Education Organisations
AUT University
Lincoln University
Massey University
University of Auckland
University of Canterbury
University of Otago
University of Waikato
Universities New Zealand
Victoria University of Wellington

Museums
Auckland War Memorial Museum
Canterbury Museum
National Library
Otago Museum
Museum of New Zealand Te Papa Tongarewa, Te Papa's Mātauranga Māori scholars and leadership team

Government
Department of Conservation (DOC)
Department of Internal Affairs, National Library
Environmental Protection Authority (EPA)
Ministry of Business, Innovation and Employment (MBIE)
Ministry for Culture and Heritage
Ministry for the Environment (MfE)
Ministry for Primary Industries (MPI)
New Zealand's Biological Heritage Science Challenge
Office of the Prime Minister's Science Advisory Committee
Parliamentary Commission for the Environment
State Services Commission
Sustainable Seas Science Challenge
Te Puni Kōkiri
Tertiary Education Commission

Appendix 4: New Zealand's taxonomic collections

Nineteen important biological taxonomic collection holders were surveyed about their holdings and associated activities. Information collected included information about: history and description of these collections, specimens, type collection, associated collections' database, relationships, outputs, who uses the collection and associated staff and why, and any references. A summary of the information is shown below:

Collection	What it Holds	Ownership	Funding	Databases	Legal or other Protection	Users	New Zealand benefit
Allan Herbarium	New Zealand's largest herbarium containing representatives of all phyla of the plant kingdom. Two thirds of the specimens are of indigenous plants with the remainder divided between naturalised, cultivated, and foreign specimens. There are over 630,000 specimens and over 2,700 type specimens.	Landcare Research	MBIE/Crown Research Institute (CRI) Core Funding; commercial income	Approximately 30% (over 240,000 specimens) has been data based using the Landcare Research Collection Information System, and is available online. Linked to the New Zealand Virtual Herbarium, and Global Biodiversity Information Facility.	Operating principles within Statement of Core Purpose state that they will "maintain its databases, collections and infrastructure and manage the scientific and research data it generates in a sustainable manner, providing appropriate access and maximising the reusability of data sets".	New Zealand CRIs, museums and universities; DOC; EPA; MPI; iwi; Regional Authorities; international research institutes and museums; general public.	A record of the flora of New Zealand, which is readily available to researchers, regional and national authorities, and interested public; a record of plants that once occurred in habitats that have been destroyed since European land use; provides identification of specimens from border interceptions; provides information on presence and biostatus of plants in New Zealand.
Canterbury Museum natural history collections	A collection of New Zealand, Pacific, Antarctic and global marine and terrestrial phyla. There are 400,000 lots, and 5,000 type specimens.	Canterbury Museum	Local Councils	50% of the collection is databased, but with only limited of records available online.	Canterbury Museum Trust Board Act 1993	New Zealand universities, Te Papa, MPI, DOC, International research institutes.	Taxonomic research and teaching; biosecurity specimen identification.
Cawthron Institute Culture Collection of Microalgae	Contains more than 250 cryopreserved strains of toxic microalgae and cyanobacteria, mainly from New Zealand but also including international samples from Antarctica, the Pacific, and beyond. There is also a living collection of nearly 200 marine toxic microalgae.	Cawthron Institute	MBIE/Backbone contract	Whole collection is catalogued, but information on each species is not data based.	MBIE grant (CAWX0902)	Cawthron Institute, international institutes, industry, New Zealand Universities, AgResearch, regional councils, MfE, MPI, MBIE.	Supports the MBIE Safe New Zealand Seafood programme; influences international biotoxin regulations for seafood exports; research and training; provision of certified analytical reference material; supports national marine biotoxin and phytoplankton monitoring programmes to prevent human death and illness in NZ and ensure market access for NZ seafood.

Collection	What it Holds	Ownership	Funding	Databases	Legal or other Protection	Users	New Zealand benefit
Dame Ella Campbell Herbarium	A collection of native and exotic plant specimens, mainly from the lower North Island. The herbarium is the main repository for voucher specimens collected as part of the New Zealand Indigenous Flora Seed Bank project. 75,000 specimens and around 100 type specimens.	Massey University	TEC	20% of the collection is databased.		Massey University, AgResearch, Plant & Food Research.	Supports research and teaching.
University of Otago Geology Museum	Fossils from the South Island of New Zealand, the Chatham Islands and Otago shelf, of invertebrate, microfossils, plant microfossils, and fossil vertebrates. There are 75,000 lots, and around 500 primary type specimens.	University of Otago	TEC	Only 1% of the collection is databased.		University of Otago, Otago Museum, GNS, Landcare Research, international research institutes, Te Papa and regional museums, DOC.	Supports research and teaching.
International Collection of Micro-organisms from Plants	A worldwide collection of fungal, bacterial, and chromist life from all terrestrial and aquatic environments in New Zealand, with a strong focus on plant-associated microbes. It includes one of the best collections of plant pathogenic bacteria in the world. About half of the cultures are from New Zealand. There are 19,919 cultures in the collection, and 821 type specimens.	Landcare Research	MBIE/CRI Core	100% of the collection is databased using Landcare Research Collection Information System. It is 100% online and searchable, and linked to the Global Biodiversity Information Facility.	Operating principles within Statement of Core Purpose.	New Zealand CRIs, museums and universities; MPI biosecurity; EPA; MfE; MFAT; DOC; international research institutes and universities; industry; Regional Councils.	Provides a comprehensive collection of living cultures of fungi and plant-/soil-associated bacteria isolated from within New Zealand and its offshore territories; assists the timely diagnosis of potential new plant disease outbreaks in New Zealand; for research and training.
Lincoln University Entomology Research Collection	Terrestrial and freshwater arthropods, primarily from New Zealand, including offshore islands (Three Kings, Kermadec, Chatham and subantarctic islands). 250,000 pinned insect specimens plus 5,000 slide and 20,000 ethanol collections. 63 type specimens.	Lincoln University	TEC	Around 5% of the collection is data based, on an Excel spreadsheet. 80% of the data based records are available online.		New Zealand Universities, museums and CRIs; DOC; MPI; commercial survey organisations; international museums and research organisations; Local Councils.	Supports research and teaching on New Zealand native insects and related arthropod biota and land-based bioprotection and biosecurity.

Collection	What it Holds	Ownership	Funding	Databases	Legal or other Protection	Users	New Zealand benefit
Museum of New Zealand Te Papa Tongarewa Science Collections	Collections include all plant and animal phyla from across the New Zealand region and in some cases internationally, but with a central focus on the South Pacific region. The collection includes 1,507,389 lots; 5,297 type specimens.	Museum of New Zealand – Te Papa	Ministry for Culture & Heritage	51% of specimens are entered in a KE Emu database for collections, available through an online facility, and a further 16% are registered but not databased.	Museum of New Zealand Te Papa Tongarewa Act 1992	New Zealand Universities, CRIs and museums; DOC, MPI, MBIE. MCH; international research institutes and universities; Regional and Local Councils; conservation trusts.	Supports research and training on the New Zealand biota; provides identification for fish species legislated under the New Zealand Quota Management System, and commercial fishing industry by-catch species, for the conservation and sustainable management of New Zealand's fisheries resource; assists the management of New Zealand's threatened plant species.
National Forestry Herbarium	A nationally significant collection of tree species, especially *Pinus* and *Eucalyptus* from New Zealand and from their countries of origin. It also includes flora from the Bay of Plenty. There are 28,534 plant collections (including separate fruit and/or cones), which include 4 type species.	Scion	MBIE/CRI Core	The collection is 100% databased, 90% georeferenced, and 25% imaged. All data are also accessible and searchable online.	Operating principles within Statement of Core Purpose.	Scion Forest Health Reference Laboratory; the Forest Owners Association; saw millers; researchers; DOC; MPI; EPA; Regional and District Councils; land managers; New Zealand education providers.	Supports biosecurity risk management and mitigation for the sustainability of forestry production in New Zealand; supports sustainable land management and conservation management activities; assists in the training of students.
National Forestry Insect Collection	A collection of forest insects and insects affecting timber in use. The collection contains approximately 100,000 pinned specimens and 44,000 in ethanol. The collection contains 130 paratype specimens.	Scion	MBIE/CRI Core	The collection is approximately 10% databased.	Operating principles within Statement of Core Purpose.	Scion Forest Health Reference Laboratory; national and international researchers.	Supports biosecurity risk management and mitigation for the sustainability of forestry production in New Zealand.
National Forestry Mycological Herbarium	A nationally important herbarium containing 4,741 specimens. The collection contains specimens collected from exotic, native, and urban trees. The collection contains type specimens.	Scion	MBIE/CRI Core	100% databased.	Operating principles within Statement of Core Purpose.	Scion Forest Health Reference Laboratory.	Supports biosecurity risk management and mitigation for the sustainability of forestry production in New Zealand.

Collection	What it Holds	Ownership	Funding	Databases	Legal or other Protection	Users	New Zealand benefit
National Forestry Culture Collection	A living culture collection that contains fungal and oomycete cultures, in particular pathogens that have been isolated from exotic, native and urban trees throughout New Zealand. The culture collection comprises 4796 living cultures and includes cultures isolated from the 1960s. The collection contains type specimens.	Scion	MBIE/CRI Core	100% databased.	Operating principles within Statement of Core Purpose.	Scion Forest Health Reference Laboratory; various national and international researchers.	Supports biosecurity risk management and mitigation for the sustainability of forestry production in New Zealand.
National New Zealand Flax Collection	A living collection of over 155 cultivars of cultural, economic and historical interest (selected for their leaf and fibre qualities for use in weaving and commerce); a representative collection of 96 ornamental cultivars; and some 80 provenances that represent the range of morphological and genetic forms found in the wild, from New Zealand (including Chatham Islands, sub-Antarctic Islands), Norfolk Island, and Raoul Island.	Landcare Research	MBIE/CRI Core	84 voucher specimens are databased and available using Landcare Research Collection Information System, and the relational database Ngā Tipu Whakaoranga (cultural uses of New Zealand native plants).	Landcare Research act as kaitiaki (stewards) of the Collection with due regard to the rights of Māori for whom *Phormium* is a taonga species. MOU with Te Roopu Raranga Whatu o Aotearoa (national Māori weavers guild). Treaty of Waitangi, including Waitangi Tribunal report on Wai 262 'flora and fauna' claim and the PVR Act 1987 (for ornamentals) also give ethical guidance.	New Zealand CRIs and universities; Te Wananga o Aotearoa; Māori weavers; , Te Puia; DOC; Local Government authorities; students; and community groups.	Maintains a comprehensive, living reference collection of *Phormium* cultivars and selected provenances relating to traditional Māori use, the New Zealand flax industry, ornamentals, and other selections of historic and cultural importance.
National Paleontological Collection	Principally marine macro- and microscopic animal and plant groups that possess some resistant shell or wall. The collection also contains large holdings of terrestrial spores and pollen, and significant holdings of terrestrial macroscopic Plantae and Chordata. Ca. 3-5 million specimens arranged in over 250,000 lots, each containing 1 to >1000 specimens. 18,000 type specimens.	GNS Science	MBIE/CRI Core	Approximately 57% of the collection is databased, with an in-house designed relational database. Linked to the Fossil Record Electronic Database.	Operating principles within Statement of Core Purpose.	New Zealand Petroleum and Minerals; overseas and domestic companies; International Ocean Discovery Programme; New Zealand and international universities and research institutes; MPI; New Zealand Police; New Zealand Commerce Commission.	Supports New Zealand paleoclimate and taxonomic research and teaching; provides the correlation and dating of geological strata, and development of the geological timescale, as part of early geological mapping and resource exploration; supports educational outreach, forensic investigations, and the testing of honey products.

Collection	What it Holds	Ownership	Funding	Databases	Legal or other Protection	Users	New Zealand benefit
Natural Science Department of the Auckland War Memorial Museum	The collection covers Auckland district (upper North Island), New Zealand, regional Pacific Islands and worldwide. Specimens include algae, marine invertebrates, fishes, plants, terrestrial invertebrates, amphibians, reptiles, birds and mammals, land snails, and fossils (many phyla, mostly mollusca). There are over 490,000 specimen lots, and 8,047 type specimens.	Auckland Museum	Auckland Council, supplemented by grants, sponsors, donors, and commercial activities.	75% of holdings are registered in Vernon Collection management database system and can be publicly searched on Collections Online, and are part of the New Zealand Virtual Herbarium.	The Auckland War Memorial Act 1996.	New Zealand universities, museums and CRIs; international research agencies; DOC; Auckland Zoo.	Supports research and teaching; records and preserves the history and environment of the Auckland Region, New Zealand, and the South Pacific; involves and entertains people to enrich their lives and promote the wellbeing of society.
New Zealand Cetacean Tissue Archive	A DNA archive of marine cetaceans (whales, dolphins and porpoises) from around New Zealand's Coastline and the South Pacific region. There are 2,400 samples. No type specimens.	University of Auckland	TEC	100% of the collection is electronically data based, using FileMaker, but not available online.	Public good data and taonga collected with permission of DOC and iwi.	DOC; iwi; MPI; New Zealand universities and museums; international research agencies.	Supports research and teaching about New Zealand's cetaceans; informs MPI's by-catch population genetics for Maui and Hector's dolphins; supports the New Zealand threatened species listing process.
New Zealand Arthropod Collection	The world's largest collection of New Zealand terrestrial Arthropoda, with major focus on insects, spiders, mites, and nematodes. There are also small holdings of other terrestrial invertebrates such as Oligochaeta and Onychophor. Approximately 1.5 million pinned dry specimens and over 5.5 million specimens in ethanol. There are around 2,600 type specimens.	Landcare Research	MBIE/CRI Core	Approximately 4% of the dry specimens are databased and web accessible using Landcare Research Collection Information System e.	Operating principles within Statement of Core Purpose.	New Zealand CRIs, museums, and universities; AsureQuality; MPI Biosecurity; DOC; EPA; MfE; MFAT/NZAid; industry; iwi; schools; Auckland Council; international research institutes and universities; Secretariat of the Pacific Community, UN Food and Agriculture Organisation; Pacific Island countries; BioNET.	Provides a collection of New Zealand terrestrial arthropods; provides vouchered data on presence in the country, distribution, ecology, and life history of arthropods to support biosecurity and conservation; supports associated biosystematic research and training; assists host-testing for bio-control measures.

Collection	What it Holds	Ownership	Funding	Databases	Legal or other Protection	Users	New Zealand benefit
New Zealand Fungal & Plant Disease Collection	Primary source of information on the fungi of New Zealand and of Pacific island countries. All the major groups of fungi are represented, with the emphasis on the plant parasitic microfungi and wood decay basidiomycetes. Indigenous fungi are well represented. Contains 100,000 dried fungal specimens, and 2,498 type specimens.	Landcare Research	MBIE/CRI Core	100% of the collection is databased using Landcare Research Collection Information System, and searchable online. The database links with the New Zealand Virtual Herbarium and the Global Biodiversity Information Facility.	Operating principles within Statement of Core Purpose.	New Zealand CRIs, museums and universities; MPI biosecurity; DOC; international research institutes and universities.	Maintains a comprehensive record of all fungal species in New Zealand; supports taxonomic and systematic research and training; supports biosecurity risk assessments for parasitic and 'weed' fungi and assists with issues relating to trade in agriculture commodities; and assists identification and listing of threatened species.
NIWA Marine Invertebrate Collection	The NIWA collection is probably the largest marine invertebrate faunal collection in the country and uniquely contains invertebrates from New Zealand's EEZ, the Ross Sea and some Pacific Islands. The collection holds over 300,000 lots of marine invertebrates, and over 3,700 type lots.	NIWA & some clients	MBIE/CRI Core	Approximately one third of the collection is captured in the electronic Specify database. The remaining, pre-NIWA, collections are registered in an Access database (AllSeaBio).	Operating principles within Statement of Core Purpose.	NIWA; NZ universities; commercial clients; Te Papa; MPI; DOC; EPA; MfE; MFAT; NZ Police; Regional Councils; international research institutes and universities.	Commercial Environmental Impact Assessments; providing identification of specimens for biosecurity inspections; training of fisheries observers; providing forensic evidence in court cases; fulfilling regulations of the EEZ and Continental Shelf Effects Act; supporting the management of New Zealand fauna under the Conservation Act; supporting New Zealand's ambition under international treaties; reporting on State of the Environment; providing information on nuisance algae distribution.
Otago Museum Taxonomy collections	The Museum houses a rich collection of invertebrate, vertebrate, botanical, and geological material, including one of the largest New Zealand spider collections and one of the most comprehensive collections of moa specimens in the world. The collection contains over 300,000 specimens and over 2,000 type specimens.	Otago Museum	Local Council	90% of the collection is data based and available online	Otago Museum Trust Board Act 1996.	New Zealand museums and universities; international research institutes and universities.	Research and teaching.

Collection	What it Holds	Ownership	Funding	Databases	Legal or other Protection	Users	New Zealand benefit
Otago Regional Herbarium	New Zealand's largest University-based herbarium containing representatives of all phyla of the plant kingdom with strengths in the Otago flora, alpine, and subantarctic flora and New Zealand lichens. The herbarium holds ca. 70,000 specimens and over 140 type specimens.	University of Otago	TEC	Approximately 20% of specimens have been databased using the globally recognised collections software "Specify". Images and information on types are available online. Linked to the New Zealand Virtual Herbarium.		National and international researchers from museums and Universities; New Zealand CRIs; DOC; regional authorities; general public; undergraduate and postgraduate training in taxonomic, biosecurity and curatorial skills and procedures.	Research and teaching; a fully MPI-compliant plant containment facility available for national and international specimen exchanges; provides biochemical, genetic, morphological and historic information pertaining to extinct or rare species, undescribed native species and newly colonising exotic species.
University of Auckland Paleontology Collection	New Zealand fossil animal, macro and micro plants, and ichnofossils. There are 44,500 collection lots (encompassing over 2 million fossil specimens), and 1,800 type specimens.	University of Auckland	TEC	89% of the collection is databased, but it is not available online		New Zealand universities; Te Papa, Auckland Museum; GNS; DOC; international research institutes and universities.	Research and teaching.
Unitec Herbarium	New Zealand native plants, lichens, and invasive species. Over half the collection are lichens, with particular strengths in northern North Island lichens, lichens of mangroves, lichens of the Waitakere Ranges, Rangitoto Island, Kermadec Islands, and Chatham Islands, and urban lichens. 7,780 specimens. 1 type specimen.	Unitec	TEC	99% of the collection is data based on Filemaker Pro and linked to the New Zealand Virtual Herbarium.		Unitec; DOC; Auckland Council; Ngāti Whātua.	Research and training; information about threatened New Zealand species; information about invasive plants.
University of Canterbury Herbarium	New Zealand terrestrial vascular plants, lichen and bryophytes, with an emphasis on Southern Alps in Canterbury, but with some overseas specimens (Philippines, Australia). 41,000 specimens, including 12 type specimens.	University of Canterbury	TEC	None	None	University of Canterbury, DOC.	Research and training.

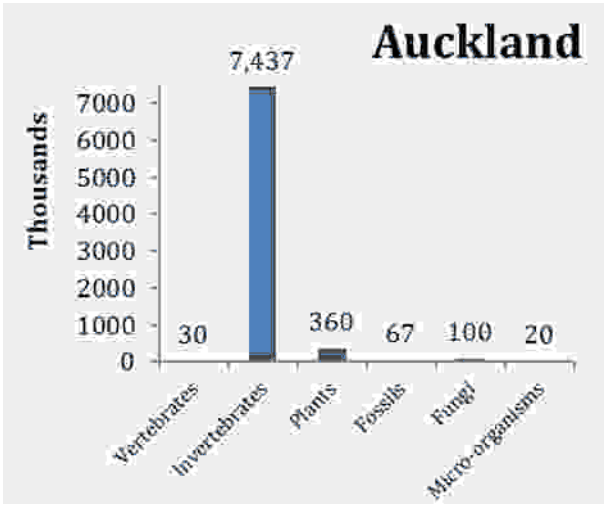
Other Relevant collections

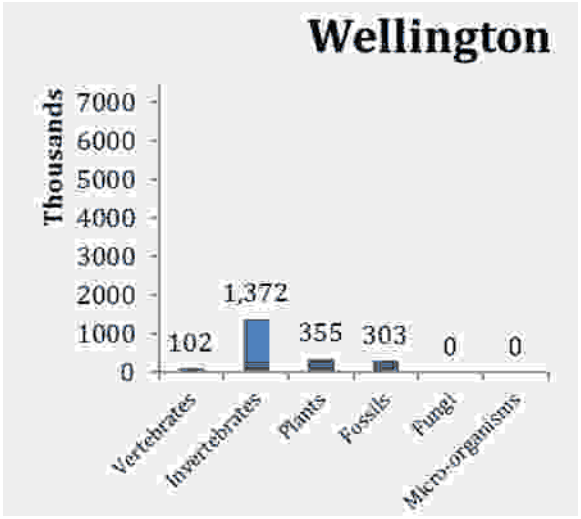
- ***New Zealand Reference Culture Collection*** (ESR) - holds approximately 4,000 strains of medically important bacteria. Some strains of use in the veterinary, dairy, and industrial fields are also held.
- ***South Canterbury Museum*** – regional and historical specimens (2,000 geological, 9,000 zoological).
- ***University of Waikato Herbarium*** - Native, adventive and cultivated plants found in New Zealand and its offshore islands, and a small collection of bryophytes and lichens from Antarctica. The flora of the Waikato region is well represented. 20,000 specimens.
- ***Waitomo Caves Discovery Centre*** - An extensive collection of fossil bird, bat and insect skeletons uniquely preserved for thousands of years in the stable cave environment.
- ***Whanganui Museum animal collections*** – includes one internationally significant modern cetacean holotype (whole skeleton).

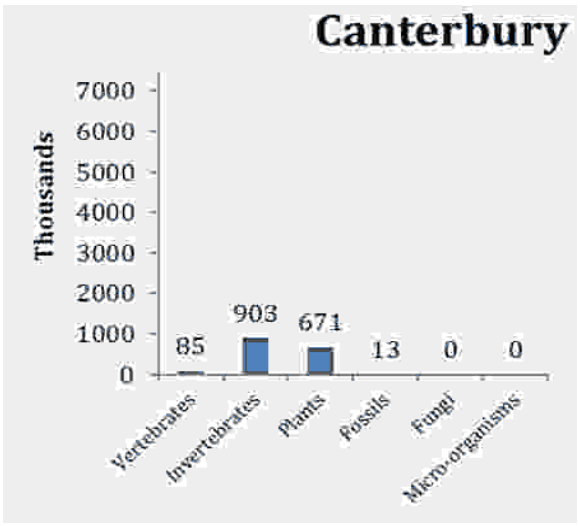
Phylum holdings of New Zealand's national taxonomic collections

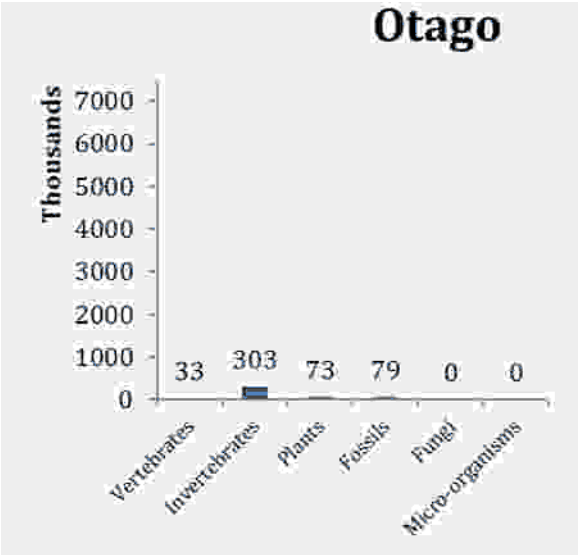
Phylum (lots)	Kingdom - Plantae	Paleontological - Total Fossils (Biological)	Kingdom - Fungi	Micro-organisms & plant pathogens	Vertebrates	Invertebrates	Total
NIWA Marine Invertebrate Collection	0	0	0	0	0	300,000	300,000
National Forestry Herbarium (Scion)	31,034	0	0	0	0	0	31,034
National Forestry Insect Collection (Scion)	0	0	0	0	0	144,000	144,000
National Forestry Mycological Herbarium (Scion)	0	0	4,741	0	0	0	4,741
National Forestry Culture Collection (Scion)	0	0	0	4,796	0	0	4,796
Cawthron Culture Collection of Microalgae	450	0	0	0	0	0	450
Dame Ella Campbell Herbarium	75,000	0	0	0	0		75,000
National Paleontological collection (GNS Science)	0	250,000	0	0	0	0	250,000
New Zealand Arthropod Collection (Landcare Research)	0	0	0	0	0	7,000,000	7,000,000
Allan Herbarium (Landcare Research)	630,000	0	0	0	0	0	630,000
New Zealand Fungal and Plant Disease Collection (Landcare Research)	0	0	100,000	0	0	0	100,000
International Collection of Micro-organisms from Plants (Landcare Research)	0	0	0	19,919	0	0	19,919
National New Zealand Flax Collection (Landcare Research)	235	0	0	0	0	0	235
University of Canterbury Herbarium	41,000	0	0	0	0	0	41,000

Phylum (lots)	Kingdom - Plantae	Paleontological - Total Fossils (Biological)	Kingdom - Fungi	Micro-organisms & plant pathogens	Vertebrates	Invertebrates	Total
Lincoln University Entomology Research Collection	0	0	0	0	0	275,000	275,000
New Zealand Cetacean Tissue Archive (University of Auckland)	0	0	0	0	2,400	0	2,400
University of Auckland Paleontology collection	0	44,500	0	0	0	0	44,500
University of Otago Geology Museum & Herbarium	0	75,000	0	0	0	0	75,000
University of Otago Herbarium	73,000	0	0	0	0	0	73,000
Canterbury Museum Natural History Collections	0	12,778	0	0	85,000	627,660	725,438
Te Papa Science Collections	280,000	52,913	0	0	102,015	1,072,461	1,507,389
Natural Science Department of the Auckland Museum	360,266	22,210	0	0	27,200	437,111	846,787
Otago Museum Taxonomy Collections	3,000	4,200	0	0	33,300	303,000	343,500



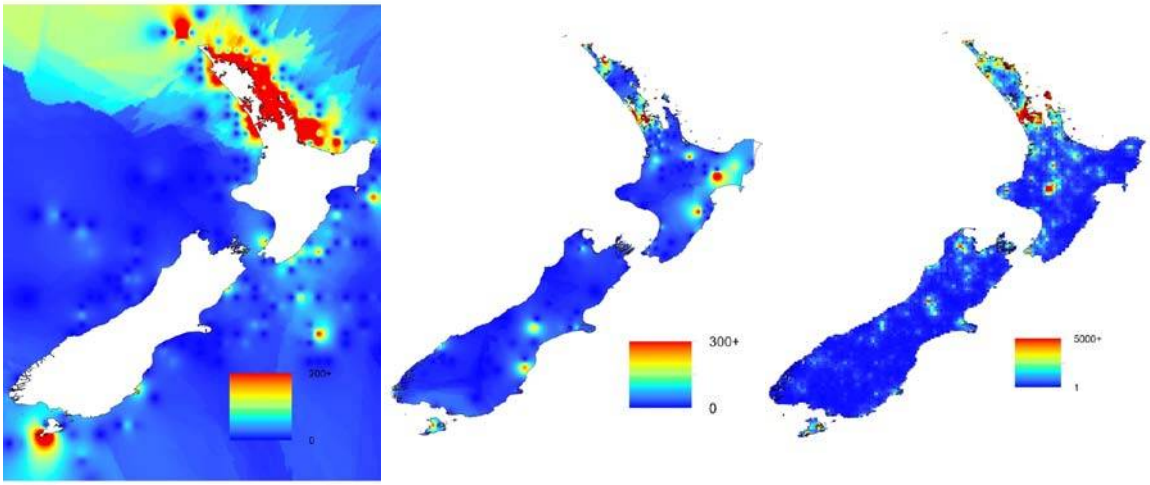






Phylum holdings of New Zealand's national taxonomic collections by region

Although collections cover similar general areas, the individual holdings of institutions have geographic variations in where material is collected from. For example, the Auckland Museum holdings of birds, plants and fish have a focus on the Auckland district and upper North Island.



Fish specimens **Bird specimens** **Plant specimens**

Auckland Museum holdings of birds, plants and fish from the New Zealand region

Number of Full Time Equivalents (FTEs) related to New Zealand's taxonomic collections

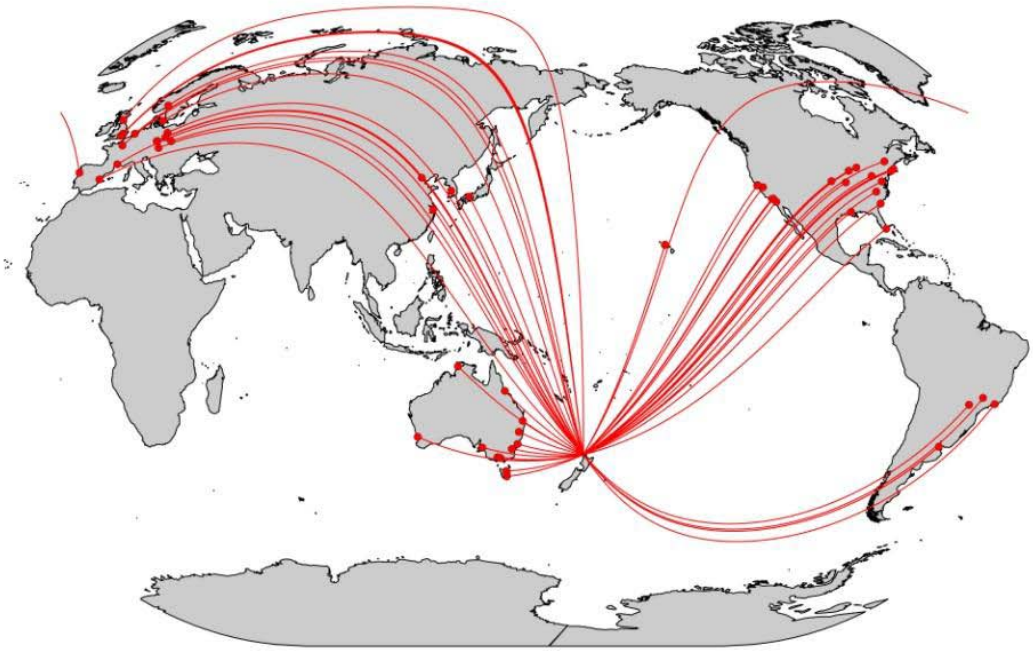
Collection Holder	FTE curation (research, taxonomy)	FTE collection management	Additional FTE (projects/ temporary funding)	Other workers
CRIs				
NIWA Marine Invertebrate Collection	3.44	1.98	7.77	Several[#]
National Forestry Herbarium (Scion)	2	0	0.25	
National Forestry Insect Collection (Scion)	0.1	0	0	0.2 of a summer student
National Forestry Mycological Herbarium (Scion)	0.1			
National Forestry Culture Collection (Scion)	0.5			
Cawthron Culture Collection of Microalgae	1	0	3	
New Zealand Arthropod Collection (Landcare Research)	0.2	2.15	4.5	
Allan Herbarium (Landcare Research)	3	0.8	3	
New Zealand Fungal and Plant Disease Collection (Landcare Research)	0.6	0.5	2.2	
National Paleontological collection (GNS Science)	0.63	0.74	0	
International Collection of Micro-organisms from Plants (Landcare Research)	3	1.5	0	
National New Zealand Flax Collection (Landcare Research)	0.4	0.4	0	
Total	**14.97**	**8.07**	**20.72**	

Collection Holder	FTE curation (research, taxonomy)	FTE collection management	Additional FTE (projects/ temporary funding)	Other workers
Museums				
Auckland Museum	2.1	2.5	7.8	9*
Te Papa Science Collections	10	6.5	6.5	20
Canterbury Museum Natural History Collections	3	5.5	0	
Otago Museum Taxonomy Collections	1.8	2	0	1.5
total	**16.9**	**16.5**	**14.3**	
Universities				
Dame Ella Campbell Herbarium	0.1	0.2		
Lincoln University Entomology Research Collection	0.2	0.2	0	various
University of Otago Geology Museum	1	0.1	10	variable
University of Otago Regional Herbarium	0	0.3	0.2	variable
University of Canterbury Herbarium	0	0	4.5	
University of Auckland Paleonotology collection	1	0.2	0	
New Zealand Cetacean Tissue Archive (University of Auckland)	0	0	0	
Total	**2.3**	**1.0**	**14.7**	
Total	**34.26**	**25.57**	**49.36**	

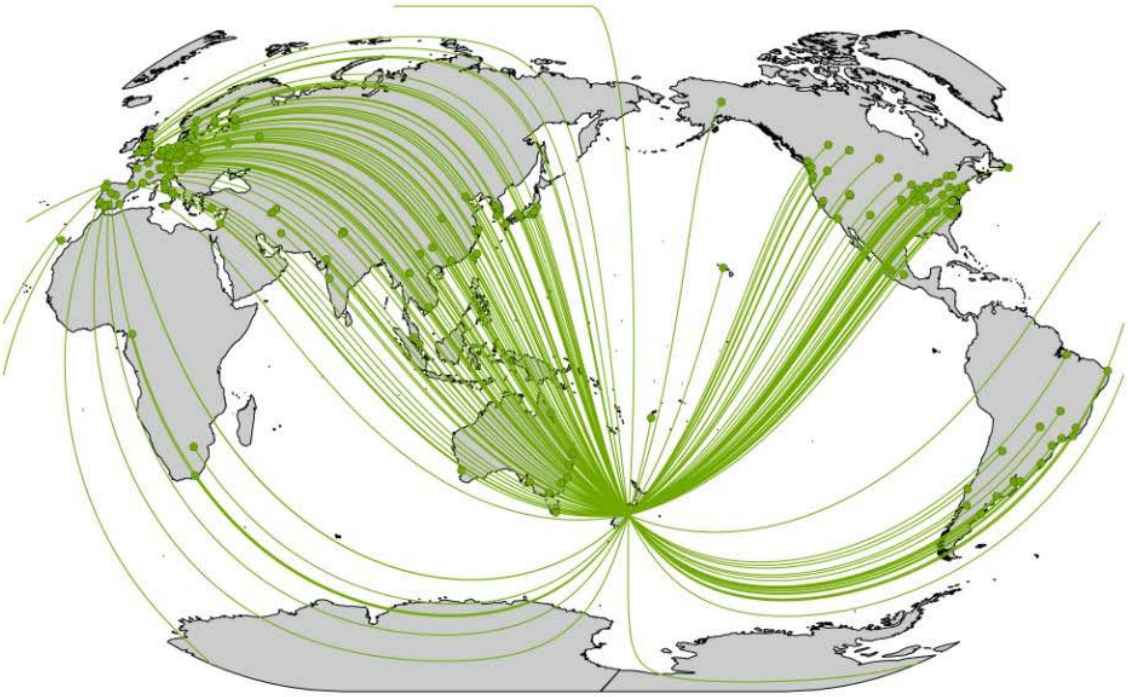
* Research Associates x 0.2 FTE each; # not NIWA Core funded

International loans of biological collections material from four institutions are shown below. The lines represent physical specimens sent/returned by each institution from 2010 to 2015. Each line represents one or more loans going to institutions overseas:

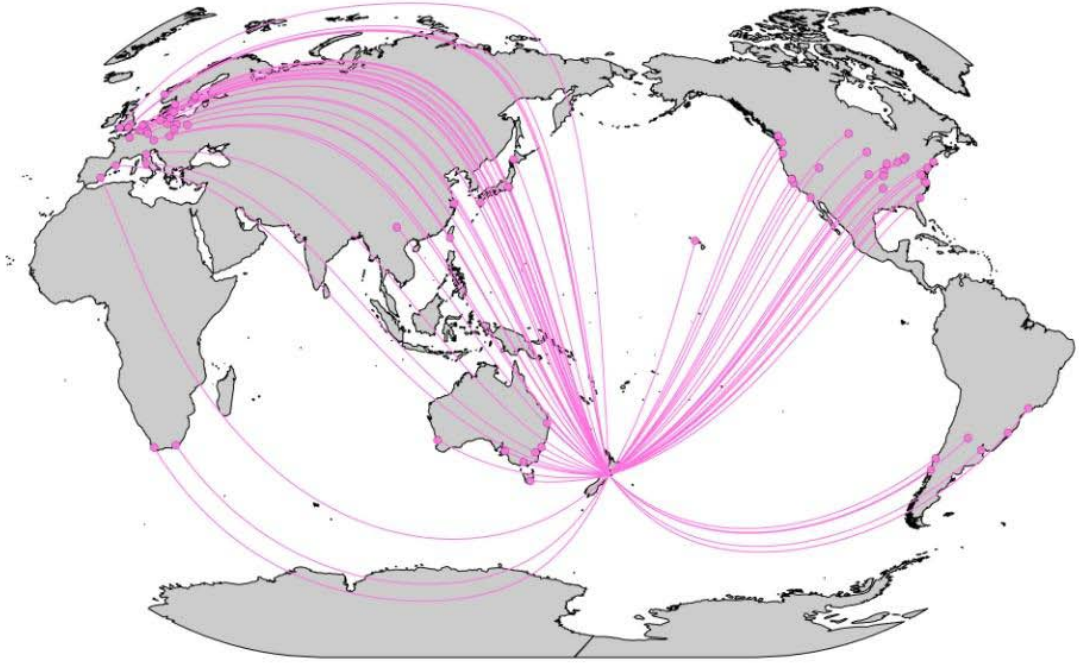
International loans of biological collections material held by Auckland Museum



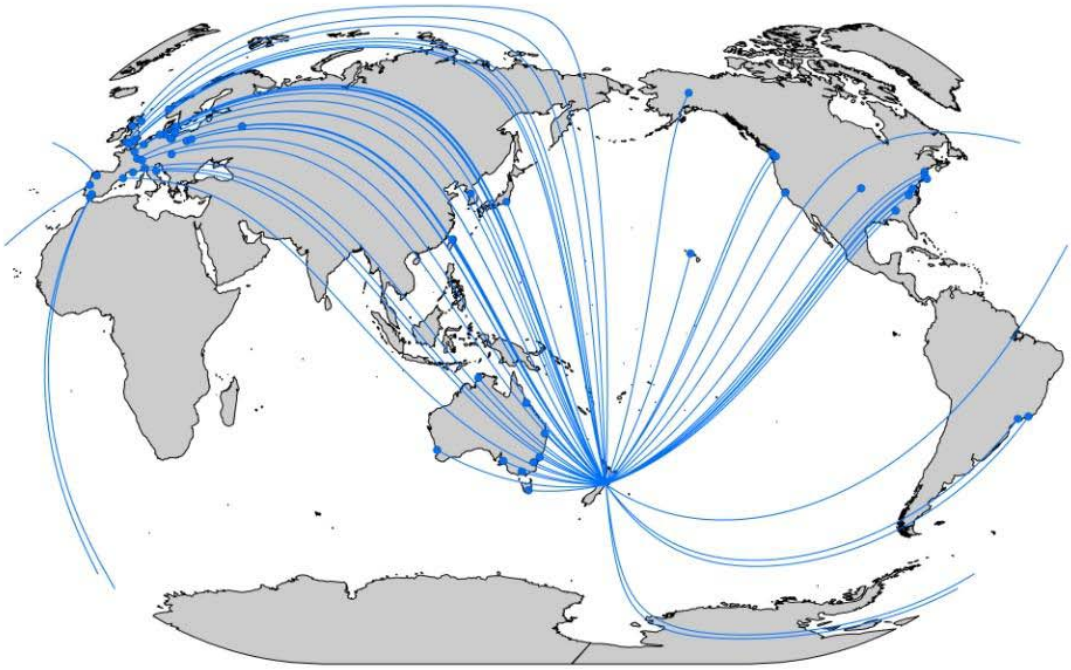
International loans of biological collections material held by Landcare Research



International loans of biological collections material held by Te Papa



International loans of biological collections material held by NIWA



Appendix 5: New Zealand's taxonomic expertise

Survey methods

At the beginning of July 2015, a questionnaire was developed based on questions used in taxonomic surveys in Canada[9] and Australia[10]. The survey was emailed via the SurveyMonkey website to a set of 150 individuals identified by the Panel as possibly having taxonomic expertise, with a month given to respond. As part of the survey, respondents were asked to identify other people with taxonomic expertise that they knew of, and 175 new names were identified through this means. The questionnaire was distributed in a second round of consultation to these people at the beginning of August 2015, and respondents given a month to respond. Over the course of the two months, 173 people responded out of the 325 contacted, resulting in a response rate of 51%. Using the statistical method of snowball sampling[11], the frequency of names repeated in the responses to the first round of questionnaires and the second round was used to estimate the size of the potential population of taxonomists across New Zealand as a whole. The estimated population using this technique was 366, with a standard deviation of 12.

Survey questionnaire

The following questionnaire was used for the survey:

1. Which of the following best describes your position?
   (University academic staff, Research scientist, Research assistant, Collection curator, Research technician or assistant, Post-doctoral student, Graduate student, Retired/volunteer, other)
2. Which of the following best describes your place of work?
   (University, CRI or publicly funded research institution, museum, other)
3. Approximately what percentage of your total work time do you spend on the following activities?
   (Taxonomic research, curation, identification, teaching, general administration/management, databasing, other; with the following options: 100%, 75%, 50%, 25%, 10%, 5>%, 0%)
4. Are you male or female?
5. Your age range.
6. Please indicate your highest formal education and training relevant to taxonomy.
   (Technical diploma, BSc, MSc, PhD, other)
7. What is your broad area of expertise (select as many that apply) and for each for each indicate the highest level of expertise:
   (algae, amphibians and reptiles, annelids, arthropods (excluding insects and crustaceans), bacteria, birds, bryophytes, cnidaria and ctenophores, crustaceans, echinoderms, fish, fossils, fungi, gymnosperms, insects, lichens, mammals, molluscs, nematodes, platyhelminthes, porifera, protists, pteridophytes, vascular plants, viruses, other, with the following options: I can recognise with keys or reference materials; I can identify species; I have written species descriptions; I have written a taxonomic revision).
8. Please approximate your published taxonomic work:
   (Journal articles, reviews, books/chapters, with the following options: 0; 1-5; 6-10; 11-20; over 20)
9. Please indicate the number of students you are currently supervising in taxonomic/systematics research:
   (MSc, PhD, not applicable)
10. Please list other taxonomists that you are aware of, and their organisation, that we can include in the next round of consultation.

Analysis

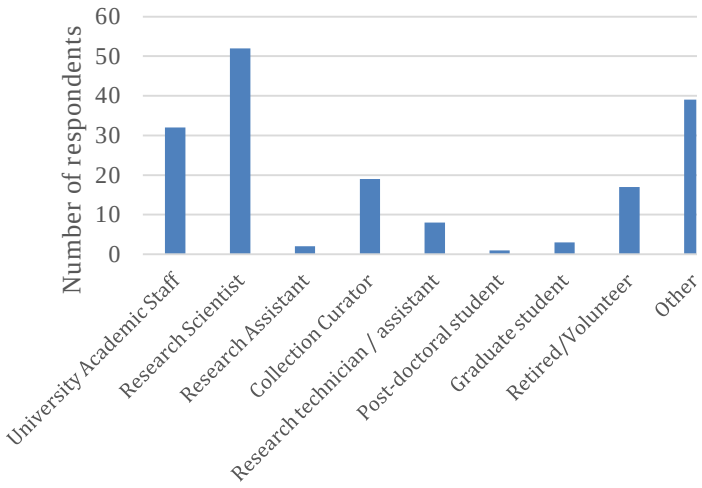
[9] http://www.scienceadvice.ca/en/assessments/completed/biodiversity.aspx .
[10] http://www.environment.gov.au/node/13879.
[11] Ove & Snijders (1994).

Respondents are reported on here in three groups:

1. ***All data*** (173 respondents): includes individuals in a range of situations: employed, self-employed, unemployed, volunteers, retired or now in other occupations. Also included are individuals with a range of expertise and specialisations: from being expert in identifying organisms from particular environments but who have not described species, to highly skilled, experienced taxonomists who have published many species descriptions and have revised higher taxa of the group they study.
2. ***Taxonomic practitioners*** (131): a subset of respondents who listed that they have described species and/or completed a taxonomic revision, have published taxonomic descriptions and can identify organisms at least in their specialty taxon. Respondents who did not claim to have identification skills in the groups of organisms they had published on but, for example, had provided specific skills or techniques to taxonomic research (e.g. phylogeography, phylogenetic analyses, informatics) are not included in this grouping. Thus, practitioners include those who have expertise across a whole organism group and have an understanding of the relationships within the group globally. This expertise is required, for example, when providing time critical biosecurity identification services or advice (See Appendix 8).
3. ***Publicly funded taxonomic practitioners*** (97): people who work in publicly funded institutions (excluding retired, volunteers, unemployed, those who work in other occupations and the self-employed, who are not automatically available to contribute to urgent identifications or national scale time-critical responses).

All data

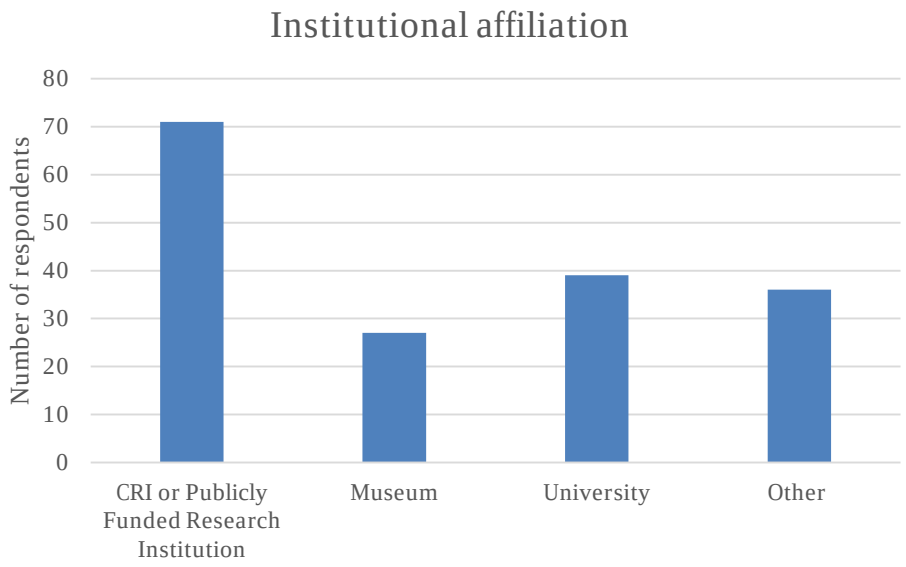
Position



Numbers of respondents in indicated positions

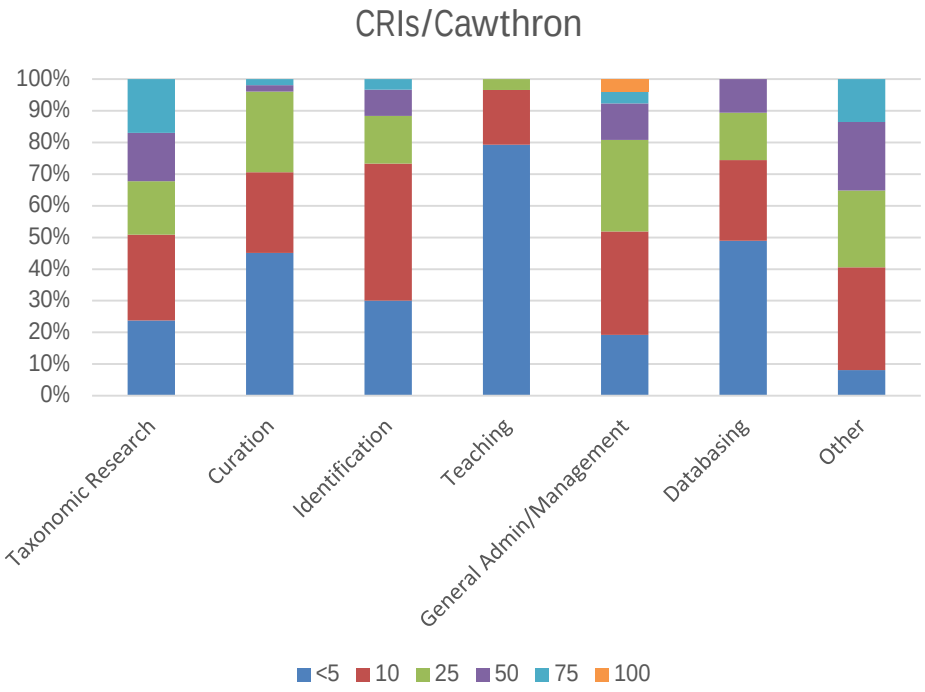
Of the total respondents, the majority were research scientists (30%) or 'other' (23%). University academics (19%), collection curators (11%), and retired/volunteers (10%) were the next most prominent positions. Research technician and assistants (6%) and graduate and postgraduate students were the least well represented (2%) in the total sample.

Place of work

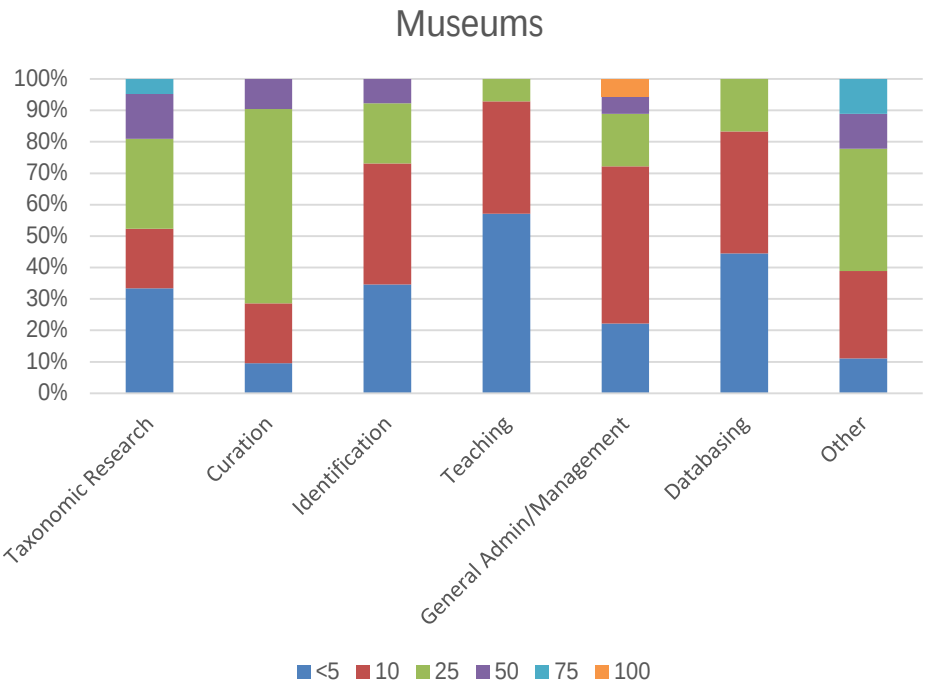


The majority of respondents are located at CRIs + Cawthron Institute (41%) with smaller numbers located at universities (23%) and museums (16%), with other locations being 21%. The latter category includes those in other occupations, working for government departments, self-employed, unemployed and retired.

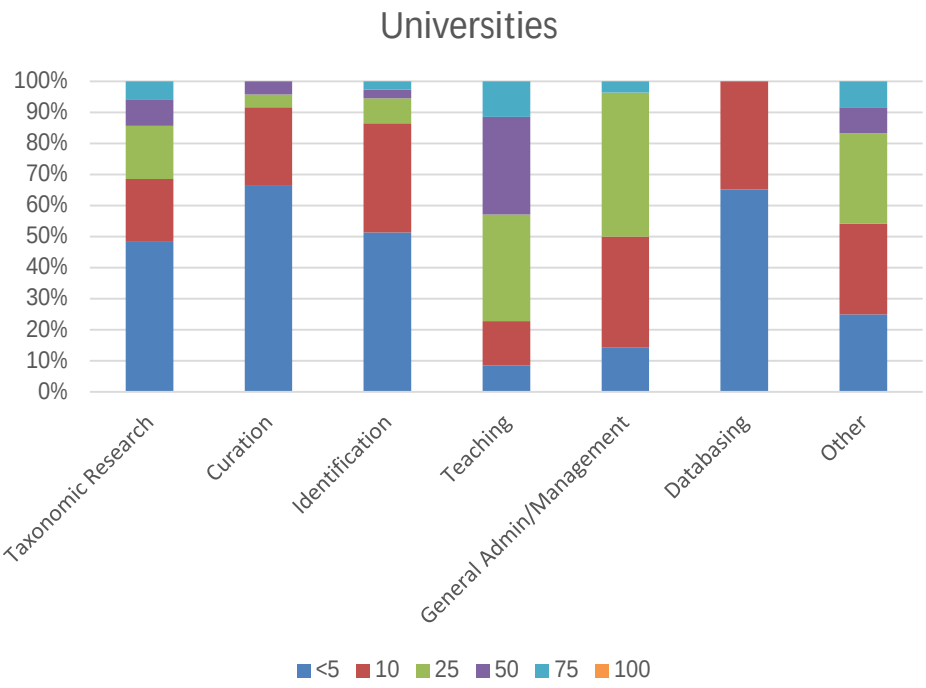
Proportion of time spent on activities



Proportion of respondents in CRIs + Cawthron Institute who undertake specified tasks, divided up according to time spent.



Proportion of respondents in museums who undertake specified tasks, divided up according to time spent.

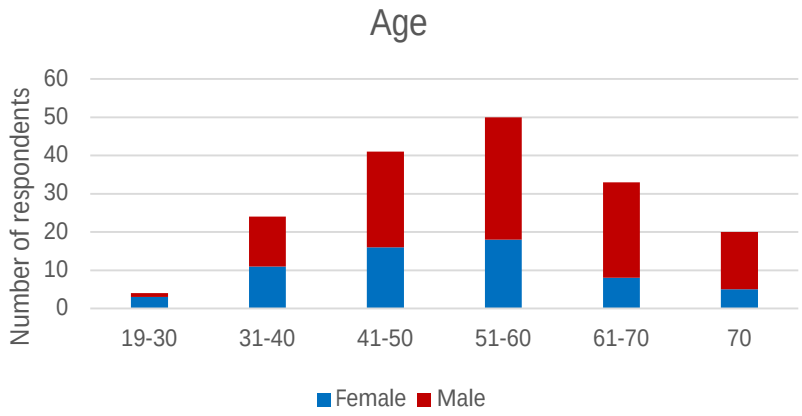


Proportion of respondents in Universities who undertake specified tasks, divided up according to time spent

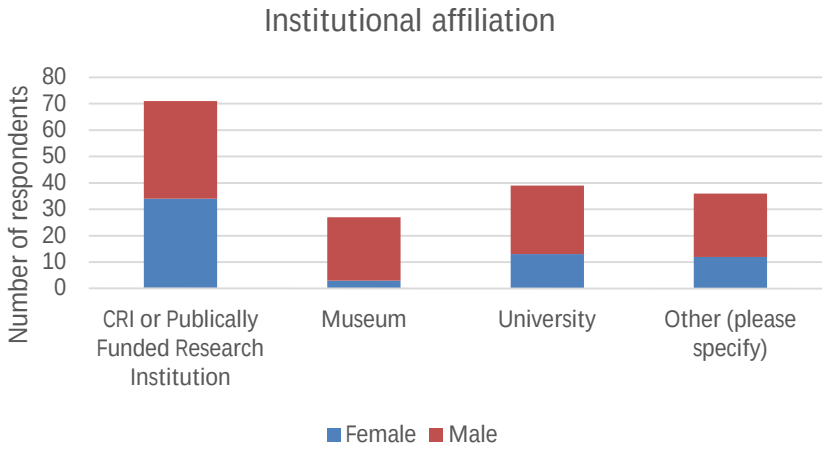
The pattern of activities undertaken by respondents depends partly on the institution they are affiliated with. For example, smaller proportions of time are spent teaching in museums and CRIs + Cawthron Institute than in universities. In museums, 70% of respondents reporting curation as an activity where they spent more than 25% of their time on this activity whereas in CRIs + Cawthron Institute 30% spend this much time on this activity and only 10% in universities. In CRIs + Cawthron Institute and museums, 50% of respondents reported 25% or more of their time being spent on taxonomic research, whereas,

30% reported being able to spend this amount of time on taxonomic research in universities. The role of retired people affiliated with institutions may be giving an inaccurate picture of the availability of taxonomic expertise. This issue will be teased out in more detail in the following section on practitioners.

Age and gender



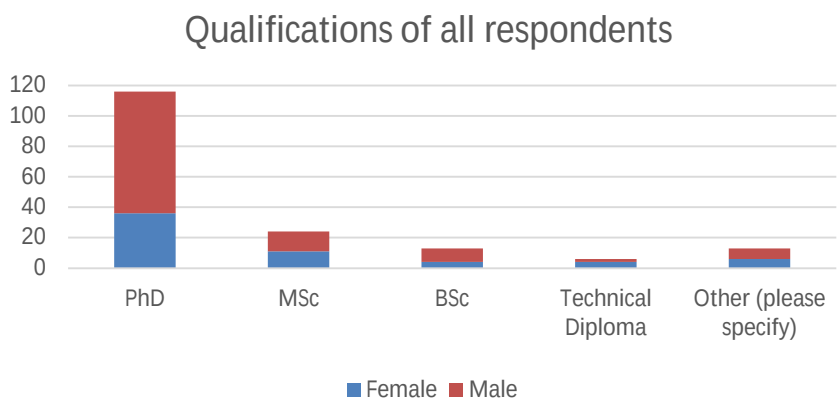
Gender distribution within each age group for all respondents



Gender distribution within institutions

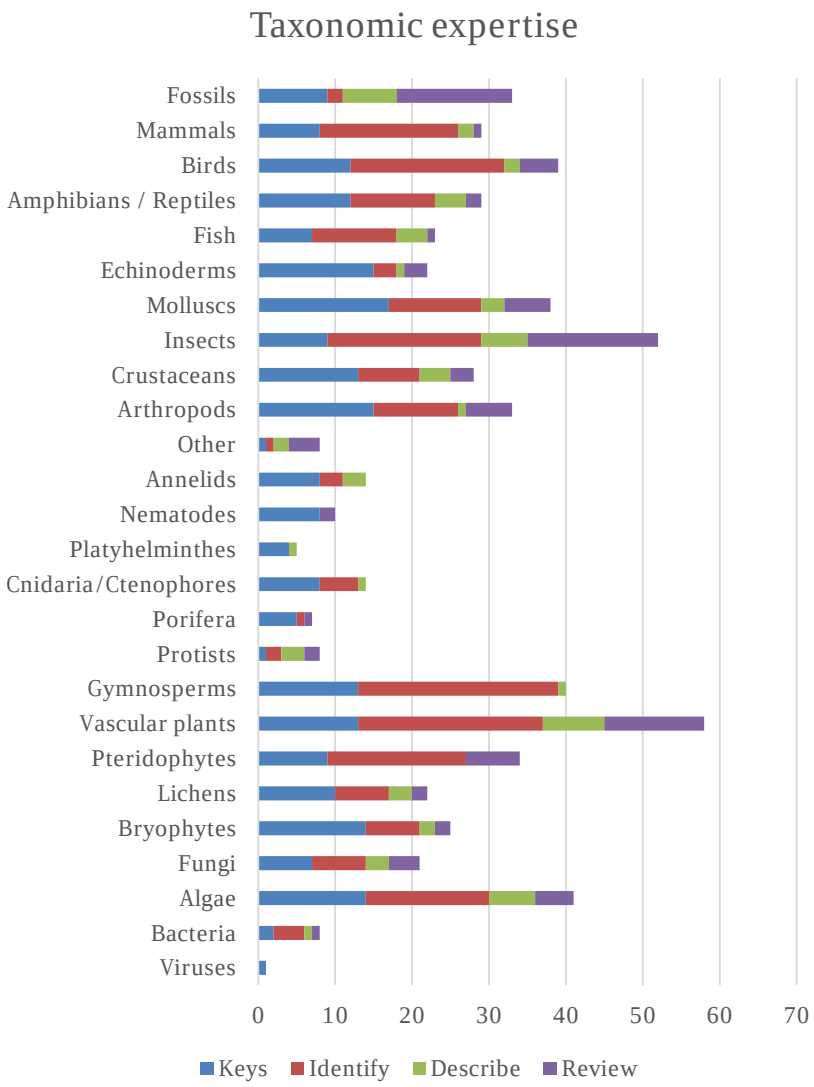
The majority of respondents were male but the proportions of male and female are more equal in the younger age groups. When these data are reported by institutional affiliation, CRIs + Cawthron Institute have more or less equal proportions of males and females, with most of the imbalance occurring at universities, museums and in other roles.

Qualifications



The majority of respondents have PhDs (67%), with the rest having a MSC, BSc, technical diploma or other qualification. Gender balance is most uneven amongst PhDs with 31% being female.

Expertise



Highest taxonomic level attained by individual respondents reported against higher level taxa/groups. The Horizontal axis shows the number of reports. Note that some individuals have skills relating to several taxa so the numbers do not add up to total respondents. Keys = I can recognise species with keys or reference materials, Identify = I can identify species, Describe = I have written species descriptions, Review = I have written a taxonomic revision.

When the highest level of expertise reported by individual respondents against each taxon/group is examined, we see that New Zealand appears to have a depth of expertise at levels Keys and Identify. That is, there is a high proportion of expertise at the level of parataxonomy where recognition of species using keys and reference material or ability to recognise species is used. Conversely, we see that high-level taxonomic expertise (describe and review) is more patchily distributed among taxa/groups, with fossils, insects, and vascular plants having the greatest number of reports. These are followed by algae and molluscs, then fungi, pteridophytes, arthropods, crustaceans, and birds. It must be remembered than in

the total data set some of this expertise is voluntary or not available for use because individual respondents are no longer employed in taxonomic positions.

Publication output

Numbers of respondents who have published varying quantities of papers, reviews or books/book chapters

Output	0	1-5	6-10	11-20	>20	Total
Journal articles	14	61	12	19	60	166
Reviews	47	40	14	2	5	108
Books/chapters	44	59	12	7	4	126

Of 173 respondents, the majority reported zero to modest levels of publication output. This will be related to either the youth of respondents, their level of funding, and/or the type of position or occupation they have. Sixty experienced respondents reported an output of more than 20 journal articles and a small number have the highest output of taxonomic revisions.

Student supervision

Reports of current supervision of postgraduate students by respondents in each type of institution

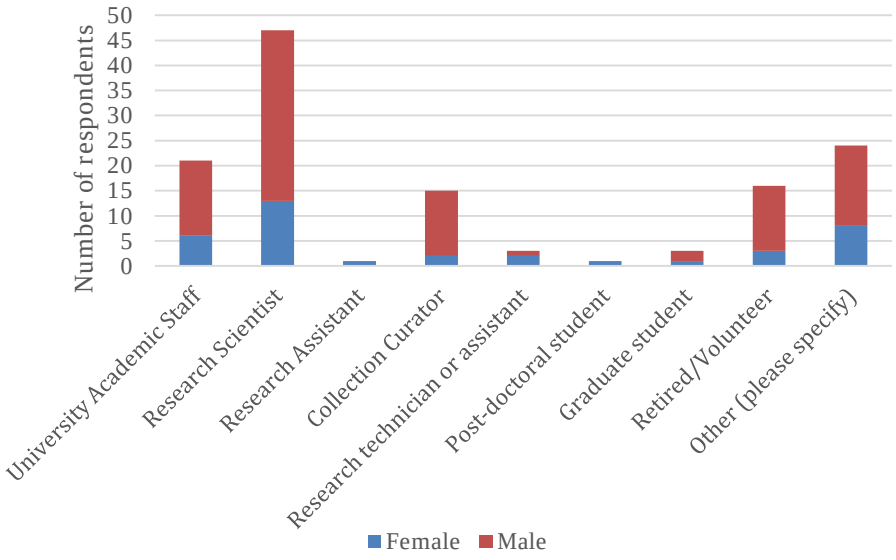
Institutional affiliation	PhD students	MSc students
CRIs + Cawthron Institute	20	15
Museums	2	2
Universities	21	12
Other	12	9
Grand Total	55	38

Fifty five respondents reported currently supervising PhD students and thirty eight reported supervising MSc students. Given that only tertiary education institutions are degree-conferring institutions, and students usually have more than one supervisor, these data do not indicate the number of students training in taxonomy. It is interesting to note the 34 instances of non-university respondents supervising students particularly among CRIs + Cawthron Institute. This can be interpreted as a relatively high level of cooperation between institutions and other individuals in the transfer of knowledge to students. It is clear that the majority of the supervised students were not represented among respondents to this survey.

Practitioners - total and publicly funded

This group of respondents are those who indicated that they have described species and/or completed a taxonomic revision (Q7), have published taxonomic descriptions (Q8), and can identify organisms at least in their specialty taxon. A subset of these are employed by publicly funded institutions.

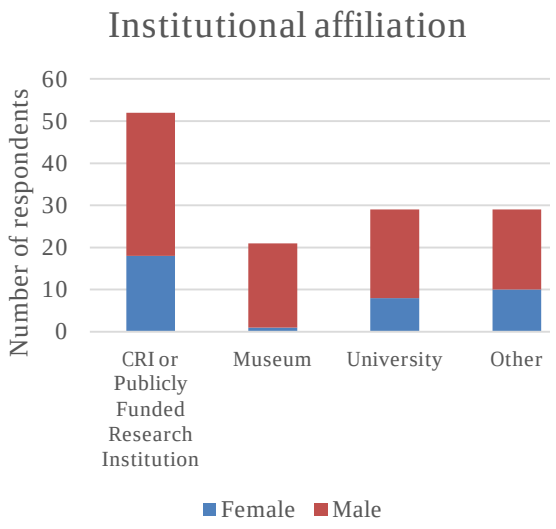
Position



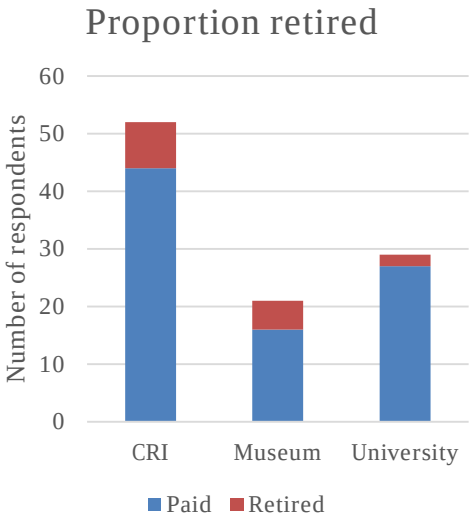
Numbers of practitioners in indicated positions

Among total taxonomic practitioners (131 respondents), the majority were research scientists (36%) or 'other' (18%). University academics (16%), collection curators (11%), and retired/volunteers (12%) were the next most prominent positions. Research technicians and assistants (3%) and graduate and postgraduate students were the least well represented (3%) in the total sample. Males dominate the profession. The 'other' category includes those in other occupations, unemployed, self-employed etc. The publicly funded subset of respondents (97) has a similar distribution among the categories of positions.

Place of work



Numbers of practitioners affiliated with particular types of institution



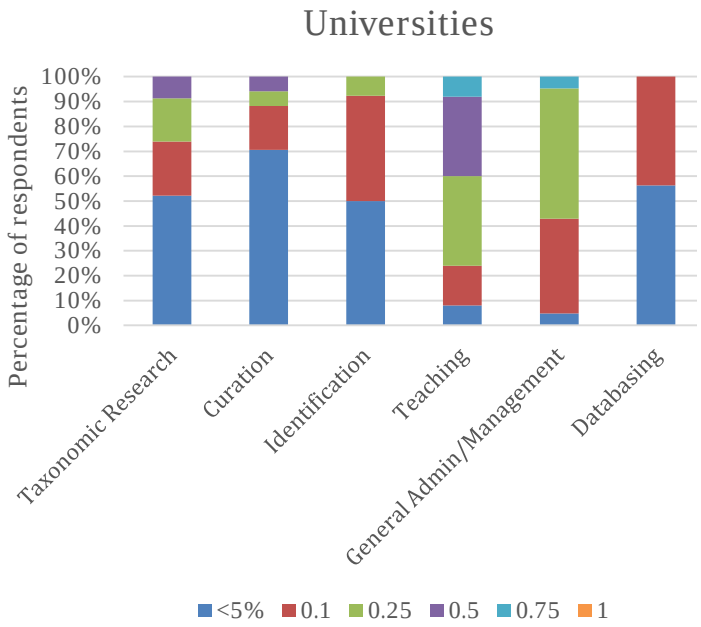
Proportion of retired / volunteers amongst practitioners

The majority of practitioners are located at CRIs + Cawthron Institute (40%) with equal numbers (22%) located at universities and other locations and slightly fewer at museums (16%). The proportion of female practitioners varies with institution: 35% at CRIs + Cawthron Institute, 5% at museums, 28% at

universities and 34% of 'other'. The proportion of retired respondents that have affiliations with CRIs, museums and universities are: 15, 24, and 7%, respectively.

Proportion of time spent on activities by publicly funded respondents

The pattern of activities undertaken by publicly funded practitioners depends partly on the institution they are affiliated with. For example, smaller proportions of time are spent teaching in museums and CRIs + Cawthron Institute than in universities. In museums, 67% of respondents reported curation as an activity on which they spent more than 25% of their time on, whereas in CRIs + Cawthron Institute, 26% spent this much time on this activity and only 6% in universities. In CRIs + Cawthron Institute, 19% reported being able to spend 25% or more of their time on taxonomic research, in museums 23%, and 17% in universities.



Numbers of practitioners in universities who undertake specified tasks, divided up according to time spent

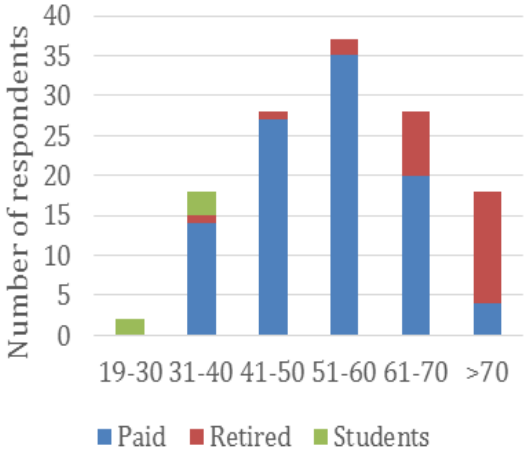
Number of publicly funded practitioners reporting being able to spend a range of their time on taxonomic research

Time	Numbers	%
0%	7	7
<5%	25	26
10%	25	26
25%	17	18
50%	13	13
75%	10	10
100%	0	0
Total responses	97	100

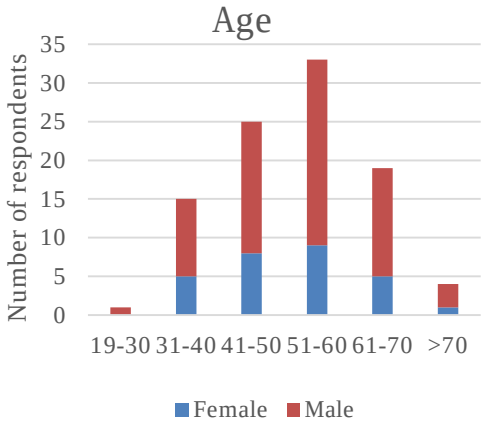
Among 97 publicly funded practitioners (deduced to be employed) a relative small proportion is able to spend a significant amount of their time on their taxonomic research. Of particular significance is the fact that 77% of all publicly funded taxonomic practitioners are funded to spend less than 25% of their

time on taxonomic research and 59% are funded to spend less than 10% of their time on taxonomic research. This suggests that highly qualified researchers are being underutilised in New Zealand.

Age and gender



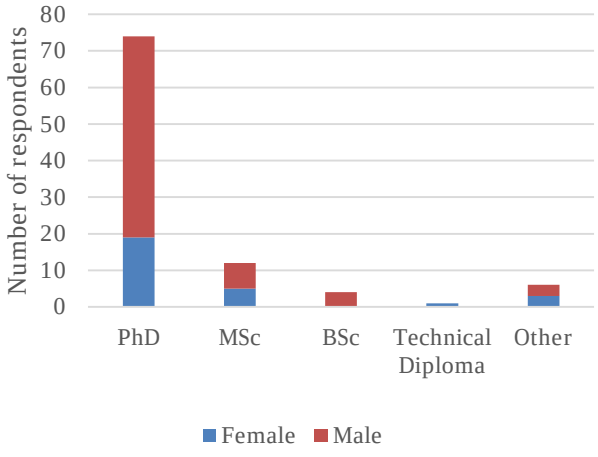
Age structure of taxonomy practitioners indicating those that are retired or students



Age and gender structure of publicly funded practitioners (employed)

Numbers of practitioners and publicly funded respondents peak in the 51-60 age range. In the 'practitioners' data set, as would be expected, students were found in the 19-30 and 31-40 age groups and retired or volunteer respondents were located mostly in the 61-70 and > 70 aged groups. The majority of publicly funded respondents were male but proportions of female respondents were slightly higher in the younger age groups: 33%, 31-40y; 32%, 41-50y; 27%, 51-60%; 26%, 61-70y; 25% >70y.

Qualifications

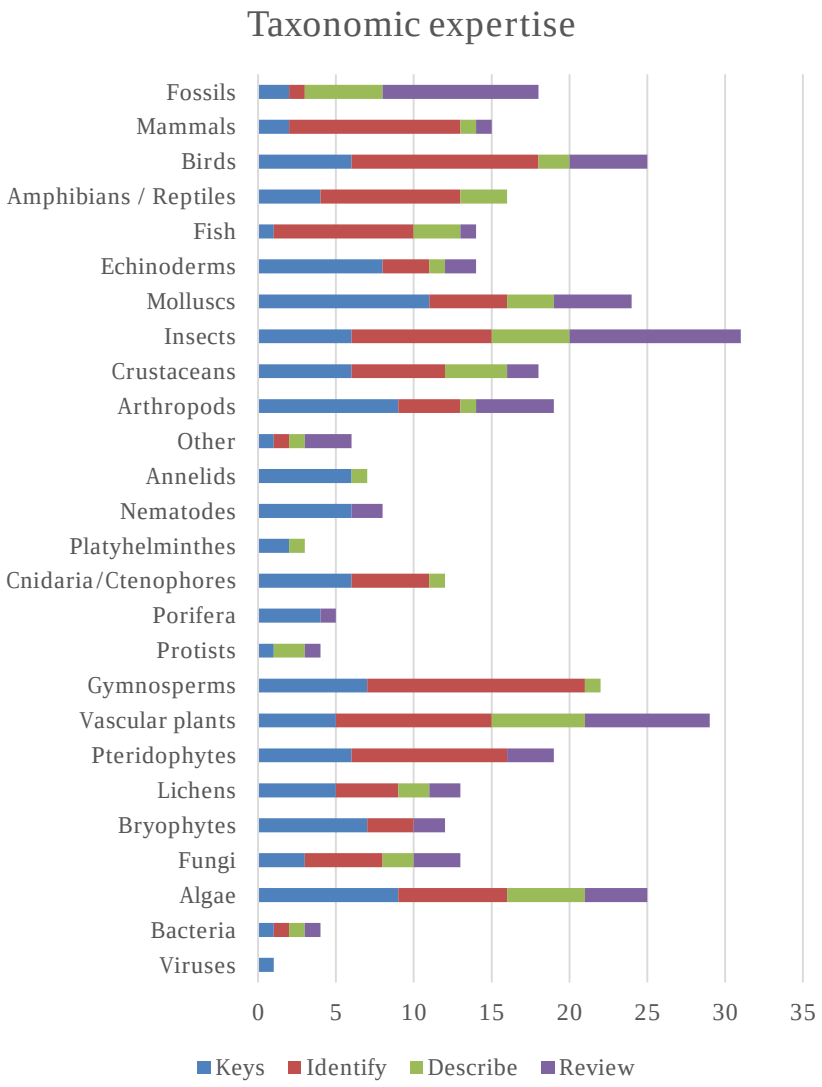


Qualifications of publicly funded respondents

Seventy five percent of publicly funded practitioners have PhDs; 12% MSc; 4% BSc; and 7% have other qualifications. Women make up 26% of PhDs and 45% of MScs.

Expertise

When publicly funded taxonomic practitioners (i.e. those who are deduced to be employed in taxonomy related work) with the highest reported level of expertise ('Describe' or 'Review') are examined against each taxon/group, we see that New Zealand has a good range of expertise at levels 'Keys' and 'Identify'. This is because a number of researchers have lower level skills in taxa other than the groups they are expert in. Nevertheless, the number of reports overall is just under half that recorded from all respondents. We also note that insects, vascular plants, and fossils have particularly high levels of "Describe' and 'Review' expertise followed by algae, molluscs, and birds.



Highest taxonomic level attained by publicly funded practitioners report against higher level taxa / groups. The horizontal axis shows the number of reports. Note that some individuals have skills relating to several taxa so the numbers do not add up to total respondents. Keys = I can recognise species with keys or reference materials, Identify = I can identify species, Describe = I have written species descriptions, Review = I have written a taxonomic revision.

Publication output

Numbers of publicly funded practitioners who have published varying quantities of papers, reviews and books/book chapters.

Outputs	0	1-5	6-10	11-20	>20
Journal articles	1	32	6	17	39
Reviews	21	24	10	2	4
Books/chapters	20	34	10	5	4

Of the total number of publicly funded practitioners, the majority reported zero to modest levels of publication output. This will be related to either the youth of respondents, their level of funding and/or the type of position or occupation they have. Thirty nine experienced individuals report an output of more than 20 journal articles and a small number have the highest output of taxonomic revisions.

Student supervision

Reports of current supervision of postgraduate students by publicly funded practitioners at each type of institution.

Place of work	PhD students	MSc students
CRI or publicly funded research institution	16	11
Museum	2	2
University	16	10
Other	7	6
Grand Total	**41**	**29**

Reported current supervision of postgraduate students by publicly funded practitioners is similar but slightly lower than that from the total data set because of the absence of retired or otherwise employed researchers from this data set. This indicates the value to New Zealand of the 'retired' and 'other' category in answers to Q1.

Appendix 6: Universities research-informed taxonomic training

A sample of universities was approached through Universities New Zealand to review the taxonomic training being undertaken in New Zealand. Data obtained from Lincoln University, University of Auckland, University of Canterbury, University of Otago, University of Waikato and Victoria University of Wellington are presented below:

1. *Courses and their enrolment numbers in the 2014 academic year at undergraduate and Masters level that supported skill development related to taxonomy, systematics or curation for plants, algae, fungi, animals, micro-organisms, and their fossils.*

Massey University		**University of Auckland**		**University of Canterbury**		**Victoria University of Wellington**		**Lincoln University**		**University of Otago**		**University of Waikato**	
Course	2014 enrol.	Course	2014 enrol.	Course	2014 enrol.	Course	2014 enrol.	Course	2014 enrol.	Course	2014 enrol.	Course	2014 enrol.
120.218	25	BIOSCI 101	1217	BIOL113	175	Biol114	336	ECOL202	80	BIOC352	73	BIOL201-14A	50
120.303	7	BIOSCI 102	292	BIOL215*	23	BIOL222	92	ECOL308	18	BIOL123	140	BIOL223 -14B	30
199.211	70	BIOSCI 103	340	BIOL305	22	BIOL219	69	ENTO304	19	BTNY223	38	BIOL226-14T	30
199.310	24	BIOSCI 104	327	BIOL375	14	BIOL227	108	ENTO612	1	BTNY225#	46	BIOL214	21
		BIOSCI 204	249	BIOL421	1	BIOL228	163	PHSC107	107	BTNY326	30	BIOL241-14A	61
		BIOSCI 207	193	BIOL472	6	BIOL370	23	PLSC21	22	BTNY467	8	BIOL312-14A	93
		BIOSCI 208	93	WATR203	14	BIOL329	121	PLSC104	235	EAOS111	208	BIOL313-14	80
		BIOSCI 209	148			BIOL430	4			GEOL263	38	BIOL314	79
		BIOSCI 210	137			BIOL529	10			GEOL363	28	BIOL338-15	59
		BIOINF 301	39							GEOL427	5		
		BIOSCI 320	39							MARI202	35		
		BIOSCI 322	47							MARI302	57		
		BIOSCI 323	47							MARI401	10		
		BIOINF 701	11							ZOOL221	121		
		BIOSCI 729	12							ZOOL222	107		
		BIOSCI 733	16										
		BIOSCI 730	17										
		EARTHSCI 103	200										
		EARTHSCI 202	45										
		EARTHSCI 303	30										
Total	**126**		**3,499**		**255**		**926**		**482**		**944**		**503**
Overall Total													6,735

*only offered in odd years -2013 figure; # not run in 2014 due to staff changeover

2. *Enrolment numbers in the 2014 academic year for taxonomic research at Masters and PhD levels for plants, algae, fungi, animals, micro-organisms, and their fossils.*

Lincoln University

- 4 PhD students doing taxonomy on weevils, fruit flies, psyllids and spiders
- 1 MSc student working on wētās

Massey University

- 3 MSc students (on work including molecular data for plants, and native forests)
- 7 PhD students (on work including molecular data for plants)

University of Auckland

The School of Biological Sciences does a lot of work in the molecular genetics/phylogeny/systematics/evolution areas. There are three postgraduate enrolments in parataxonomy (macrofauna), plus a student in algal taxonomy (through Joint Graduate School in Marine Science with NIWA).

University of Canterbury

- 1 MSc student (flowering plants)
- 2 PhD students (mayflies, flowering plants)

University of Otago

- 1 MSc student (paleontology - plants)
- 6 PhD students (paleontology – cetacea, brachiopods, vascular plants)

University of Waikato

- 4 MSc students in plant systematics
- 10 MSc students in animal systematics
- 5 PhD students in plant, microbial, and animal systematics

Victoria University of Wellington

- 9 PhD students (taxonomy/biodiversity of sponges, spiders, viruses, algae, fungi, beetles, molluscs, and crustaceans) (note that this number is probably an underestimate, as not all staff members responded)
- 3 MSc students (algae, fungi and crustaceans)

3. *Qualitative information on other activities, such as taxonomic research programmes, and the development of tools and databases to support taxonomic knowledge creation; for plants, algae, fungi, animals, micro-organisms and their fossils.*

Lincoln University

There is specific funding of projects that promote publication of taxonomic works (Trichoderma) and expansion of taxonomic reference collections. There is also work on the integration and 'bringing to the fore' of the entomological collection within the Lincoln HUB model. There is current work on taxonomic revisions of beetles (families Carabidae, Curculionidae, Cucujidae, and Silvanidae), flies (Tephritidae), psyllids (Psyllidae), spiders (Idiopidae) and sub-Antarctic entomology, and molecular systematics research, phylogenetics, and taxonomy of a wide range of taxa (mostly terrestrial invertebrates), particularly insects and mites. There is particular interest in species delimitation and DNA barcoding, and in biodiversity monitoring, using both molecular and non-molecular approaches, which requires a sound taxonomic base. Most other research involves identifying specimens of terrestrial arthropods using taxonomic keys, etc. There is also some primary recording of plants on the Lincoln campus, including living collections of magnolias, conifers and New Zealand native plants.

Massey University

Research is being undertaken on an on-line guide to New Zealand's soil invertebrates; the development of an interactive key to terrestrial isopoda of New Zealand; soil microarthropod communities in the New Zealand high alpine environment; systematic and phylogenetic research on plants (especially native New

Zealand plants), and conservation genetic approaches to evaluating the taxonomic status of species.

University of Auckland
There is metabarcoding research being undertaken on the human microbiome, and on soil and litter communities. The latter group has been developing a database and set of resources. Work is also underway overseeing DNA Surveillance as a site for genetic identification of organisms from taxonomic groups of concern due to exploitation or trade, or for specific research interests[12].

University of Canterbury
Work is being undertaken in virology with the executive committee for the International Committee for the Taxonomy of Viruses (ICTV), and the development of software to enable viral taxonomy groups and virologists in general to analyse their sequence data. Work is also being undertaken on vascular plants around Digital Flora of the Philippines; an online taxonomic database of plant photographs; phylogenetic and taxonomic studies of Senecioneae (Asteraceae).

University of Otago
Work is being undertaken on genetic variation in humans (primarily mitochondrial DNA and Y chromosome variation); on species identification and evolution of Asian/Pacific rodent species; and on the identification of population structure in New Zealand coastal marine mammal and bird species through analyses of ancient and modern DNA. The Gemmell group has addressed a range of taxonomic questions, predominately related to questions of conservation or biosecurity using genetic and genomic approaches. Their research blends genomics with ecology, population, conservation, and evolutionary biology to examine problems in organisms ranging from invertebrates to mammals. Additional research includes:

- the evolution of several extinct and extant New Zealand bird species from ancient and modern DNA
- The Plant Extracts Research Unit has collections of New Zealand terrestrial plants with a database on collection details and their various biological activities
- Taxonomy and systematics of southern New Zealand cyclostome bryozoans
- New Zealand fungal taxonomy and phylogenetics; taxonomy and evolution of *Celmisia* (Asteraceae); Intra- and interspecific variation in New Zealand *Lobelia* (syn. *Pratia*); phylogenetics and trait evolution in *Coprosma*; taxonomy and phylogenetics of lichens; and plant viruses in New Zealand
- Paleontology programmes in geology involve taxonomy, systematics, and phylogenetics of marine and terrestrial fossils from New Zealand; new taxa of baleen whales, dolphins, penguins, and bony fish; fossil-calibrated phylogenetics of Cetacea; terrestrial fossils from shallow marine, lake, and river sedimentary rocks, including vascular plants, insects, and amber; and brachiopod taxonomy and systematics

University of Waikato

Research is focused on the taxa of New Zealand, Zealandia, and Antarctica. The University hosts the Pacific Biosystematics Research Laboratory, the New Zealand hub for the International Barcoding of Life initiative (iBOL), the University of Waikato Herbarium, The Centre for Biodiversity and Ecology Research, the Environmental Research Institute, and the International Centre of Terrestrial Antarctic Research (ICTAR). Research work includes:

- The study of endemic species of Zealandia
- Work on the International Barcode of Life initiative, with DNA barcoding initiatives in New Zealand and Antarctica
- A focus on extremophiles of Antarctica, both community associations and molecular taxonomy

[12] http://dna-surveillance.fos.auckland.ac.nz:23060/

Victoria University of Wellington

A wide range of molecular tools related to taxonomy and biodiversity are employed, including the application of DNA bar coding, metagenomics, quantitative PCR and microsatellites. Work is currently underway to develop a molecular database for mycorrhizal fungi in New Zealand, and the Allan Wilson Centre is specifically focused on the application of molecular tools for studying New Zealand biodiversity. The university has a Memorandum of Understanding with Te Papa that allows three of their staff bench and office space in the School of Biological Sciences, though this relationship is perhaps under-utilised in terms of teaching.

Appendix 7: Recent history of CRI biological collections

In 1989, in the DSIR "Review of Biosystematics and Ecological Science", it was concluded that *"scientific resources in all programmes in the Biosystematics activity area have now been reduced to a level at which viability is marginal… Quite small changes of research effort in museums and universities could dramatically affect priorities because of the limited extent of Biosystematics research in New Zealand today"*. The Ministry of Research, Science and Technology review (1995) "Biosystematics: Issues and Options for New Zealand" reported that the national capability in taxonomy had been at least halved from 1975-1995, despite the findings that 71% of users surveyed considered taxonomic research to be either important or extremely important for their business.

Collections and databases previously held in DSIR and other government laboratories were transferred to Crown Research Institutes on their establishment in the early 1990s[13]. The Foundation for Research, Science and Technology also established the terminology "nationally significant databases and collections", and a process for identifying assets of strategic national importance. All public-good science providers were invited to submit databases and collections for consideration as having a "nationally significant" designation. It was considered that they must be:

1. currently and primarily funded by the Public Good Science Fund;
2. irreplaceable, e.g. a database dependent on extended and unbroken time series data;
3. nationally and/or internationally unique; and
4. able to contribute to the Government's agreed outcomes for science by supporting scientific research.

The Foundation for Research, Science and Technology stated "Status as a strategic, nationally significant asset implies priority funding by the Foundation, but the exact level of funds involved cannot be absolutely guaranteed by the Foundation in all conditions. As a minimum, the Foundation would fund the maintenance or fixed costs of the database, or in the case of time series databases, their updating."

These databases and collections have carried their "nationally significant" terminology through subsequent generations of science investment policy that have seen the Public Good Science Fund restructured, the Foundation for Research Science and Technology disestablished and the establishment of Core Funding for CRIs in 2010.

There are currently 25 databases and collections designated as nationally significant held in Crown Research Institutes and the Cawthron Institute. These include more than biological material and associated databases[14]. There are also many other databases and collections both biological and non-biological, held in Crown Research Institutes and other research organisations that are an integral part of research programmes, but which do not carry "nationally significant" status.

It is important to note that the nationally significant designation did not include biological collections funded through other sources (for example, Ministry for Culture & Heritage - Te Papa; rate payers - Auckland, Canterbury, Otago Museums; Vote Education - universities) even though many of these Institutions' collections are significant at a national or international level.

Between 1989 and the 1995 review there were significant losses in the taxonomic workforce through redundancies, retirements, and through shifts in work responsibilities leaving less time for the remaining practitioners to engage in taxonomic work. Staff commitment to taxonomy in Crown Research Institutes, universities, and museums dropped by close to 50% between 1996 and 2002; there were 51 FTEs engaged in this work in 1996 while only 27 FTEs claimed taxonomy as a core function in 2002.

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[13] Foundation for Research, Science and Technology (1993).

[14] Foundation for Research, Science and Technology (1993).

Government funding remained static between 1996 and 2004 at ca. $7.8m per year, with the allocation being 56% for terrestrial organisms, 8% for freshwater organisms, 27% for marine organisms, and 9% for fossils. This effective decline in funding led to a consequent reduction in effort.

Outcome Based Investments (OBIs) were established in 2004 and operated until 2010. Within the OBI structure key taxonomy programmes in terrestrial (Landcare Research/Te Papa) and marine biodiversity (NIWA/Te Papa) were established, funding both the collections and databases and the associated systematic research. Investment levels reflected the previous history of investment. There was little opportunity to examine national priorities at that time.

In 2009 the Backbone Fund was implemented as a "package of change designed to create a more appropriate form of investment for those activities which form the 'backbone' of the New Zealand Research, Science & Technology (RS&T) system". There was recognition of areas of science that the government needed to support on a long-term basis for the future security and wellbeing of the nation, and which underpinned a range of activities. The science 'backbone' in New Zealand was interpreted to include essential infrastructure, nationally significant databases and collections, long-term datasets, and functions related to national and international obligations (such as the Measurement Standards Laboratory). 'Backbone' activities were recognised as having specific infrastructure needs, resulting in a higher proportion of capital cost than other science activities. It was also recognised that these areas were best suited to long term funding arrangements "as competition between providers did not provide benefits in the short to medium term." The intention was that the long term funding would result from "direct negotiation with the provider organisation(s), and periodically reviewed (ca. 5 yearly) against current and emerging priorities, to examine the excellence of the science being conducted, and delivery against expectations."[15]

Additional funding for the nationally significant databases and collections, the first for many years, was obtained as part of establishing the 'backbone' funding. However, only a few of the collections subsequently received their intended increases before the Global Financial Crisis lead to the remaining appropriation increases being reversed.

In 2010 the Crown Research Institute Taskforce Review resulted in the move to Core Funding, incorporating existing Backbone funding within it, alongside the development of a Statement of Core Purpose for each organisation, the intention being to provide "greater financial certainty in delivering outcomes of value to New Zealand".

CRI Boards were charged with investing the static core funding to: "fund science research that supports the sectors they serve, maintain nationally significant databases and collections, and maintain strategic capability to address future risks." The nationally significant biological collections housed in Crown Research Institutes are all funded through Core Funding and the Cawthron Institute through a specific Backbone contract from MBIE, and there are currently no other sources of public good funding for taxonomy and biological collections administered by MBIE.

The most recent development in New Zealand science has been the development of National Science Challenges, and most recently the National Statement of Science Investment[16]. Taxonomy and nationally significant biological collections have been explicitly excluded from the Challenges[17], as they were considered to be core scientific infrastructure of relevance to many investment approaches well beyond the mission-led research of the Challenges. The contracts for CRI core funding expire in June 2016, and

[15] MoRST (2007).
[16] Ministry of Business, Innovation & Employment (2015).
[17] Ministry of Business, Innovation & Employment (2014).

thus MBIE is undertaking a review of CRI core funding "to determine whether changes should be made to improve its effectiveness"[16].

Appendix 8: Case studies

Systematics of mites enhances safe importation of fresh produce

Research background
The publicly funded New Zealand Arthropod Collection (NZAC) at Landcare Research is the largest taxonomic collection of insects and other arthropods in New Zealand. It is integrated with research and outreach activities that are publicly or commercially funded.

Commercial problem
New Zealand imports large volumes of fruits and other fresh produce from overseas. These must be inspected by MPI staff for any potential pests including mites. This inspection holds up release of imports. Furthermore, if potential pest species are found, fumigation may occur at the port of entry. These chemical treatments can be detrimental to the environment, can reduce the shelf life of fresh produce, and increase the cost to importers, MPI, and the New Zealand consumer. Mites from the family *Winterschmidtiidae* are frequently found on imported banana and pineapple from the Philippines, Ecuador, and other countries. Lack of taxonomic knowledge about this family means it is difficult for MPI to identify mites and therefore to assess risk when these species are detected at the border.

Benefit
To solve this problem a researcher at Landcare Research, Auckland, completed a taxonomic study of winterschmidtiid mites that have been intercepted by MPI as well as specimens from the Philippines and Ecuador, the major sources of pineapple and banana. The intent was to do the underpinning taxonomic science and then develop the diagnostic tools to allow MPI staff to determine the quarantine status of these species. This project was funded by the New Zealand Fresh Produce Importers Association with collaboration and co-funding from MPI, and utilised staff capability in mite systematics underpinned by Landcare Research's core funding.

The study demonstrated that one species is frequently intercepted from banana and pineapple imported from the Philippines and Ecuador. This species can now be rapidly differentiated from species already occurring in New Zealand and species more rarely intercepted. This is possible using a taxonomic key to all relevant species. Furthermore, molecular techniques were developed that can be applied by MPI to specimens for further confirmation. These tools allow MPI and other end-users to make more informed decisions about fumigation. The study also suggests further research in risk assessment, where studies on the underlying biology can suggest the likelihood that the more commonly intercepted species could establish in New Zealand.

Taxonomy crucial to recognising New Zealand's marine biodiversity and influencing policy for protection

Research background
A 1999 taxonomic survey of a 10 x 20 square km area of seafloor adjacent to Kapowairua Spirits Bay, Northland, revealed the most biodiverse marine region for New Zealand, with exceptional species richness of sponges and bryozoans (about one third of all New Zealand species), with high levels of local endemism[18]. This area included a scallop fishery, which prompted the survey in the first place. New hydroid, gorgonian, and barnacle taxa also occurred in the benthic invertebrate assemblages of Spirits Bay, and are the richest in New Zealand in terms of numbers of species and taxon diversity.

For example, more than 200 species of sponges and 300 species of bryozoans have been recorded in Spirits Bay. The significance of the latter can be appreciated when compared to the total bryofauna of

[18] Costello *et al*. (2010)

New Zealand (951 marine species, hence 32% of species are in Spirits Bay), and Britain (302 species). Similarly, ca. 750 species of sponges are known in New Zealand, of which the Spirits Bay diversity is 27%. The area also boasts many other invertebrate taxa and high rates of local/global endemism.

The taxonomic expertise and recognition of the sponge and bryozoan species resides in the NIWA marine taxonomy research team and with key collections held in the NIWA Invertebrate Collection.

Management impact and outcome
The discovery of the hotspot led the then Ministry of Fisheries to close the area with the greatest number of species (in the 50-70 m depth zone) to trawling, Danish seining, and commercial scallop dredging, effective from 11 November 1999, to allow areas of affected habitat to regenerate. This protected area now supports the surrounding fishing industry areas. Only detailed, authoritative taxonomy allowed for the recognition of this remarkable area as New Zealand's marine biodiversity hotspot. Now, testable hypotheses based on geography, tectonics, hydrography, and the biology of the organisms themselves can be erected to explain this diversity.

Characterising Land Biota Research Portfolio underpins environmental management by regional councils

Research background
Landcare Research's Characterising Land Biota (CLB) research portfolio includes five Nationally Significant Collections and Databases: the Allan Herbarium (CHR), the National New Zealand Flax Collection, the New Zealand Arthropod Collection (NZAC), the New Zealand Fungal and Plant Disease Collection (PDD), and the International Collection of Micro-Organisms from Plants (ICMP). Each of these systematics collections has associated active research programmes, and they are each strongly linked to the needs of research users through stakeholder consultation.

Regional councils benefit immensely from access to these resources. Most Councils have limited taxonomic expertise within their own organisation. This is particularly true for certain taxonomic groups such as invertebrates and micro-organisms, which often require specialised skill-sets not present within Councils. However even for plants, Councils will frequently consult external experts to confirm identification of unusual species. Access to accurate diagnostic verification is particularly needed for Council passive and active surveillance programmes.

Benefits
One case-study project, currently being undertaken by all Regional Councils/Unitary Authorities, is the creation/revision of Regional Pest Management Plans (RPMPs). In the course of creating a new RPMP a Council will require Landcare Research resources to identity pests and their impacts. For instance, Auckland Council is expected to consult herbaria for species distribution and habitat occupancy information for around 300 plant species during its current review. Another example is the identification, surveillance and distribution records of invasive ants and wasps undertaken by staff curating the NZAC. This service helps assess risk pathways and spread of serious insect pests such as Darwin's and Argentine Ants and contributes to the management and control of these pests by Councils and other land managers. Councils across the country typically have relatively poor data on species distributions within their regions, and therefore professionally collated national collections are an invaluable resource.
The CLB also directly contributes to and underpins research and tool development for the nationally important biocontrol of weeds programme which is funded by the regional council collective. CLB staff and resources/services provide taxonomic and diagnostic support for determining suitable biocontrol agents both within New Zealand and internationally. For example the ICMP facility houses quarantine cultures of biocontrol plant pathogens prior to release and EPA approval, which is an essential service for the council programme.

The CLB portfolio is of nationwide strategic significance in relation to understanding the identity and location of native and exotic species. New Zealand's biodiversity and biosecurity (including border control) cannot possibly be managed effectively without the backup of these taxonomic resources.

Identification of toxic microalgae reduces impacts on human health

Research background and problem

The freshwater cyanobacterial part of the culture collection at the Cawthron Institute comprises 250 strains, with most being cryopreserved. Strains derive from lakes, rivers and reservoirs throughout New Zealand, and from one site in Antarctica. The cyanobacteria collection increased rapidly post 2006 due to new funding (FRST post-doctoral fellowship; MBIE-funded project on lake biodiversity and restoration). Cultures isolated during these projects were used to characterise New Zealand's toxin-producing and bloom-forming planktonic and benthic-mat-forming cyanobacteria.

Benefits

Identification of new toxin producers to inform monitoring programmes

Understanding the range of toxin-producing cyanobacteria is critical to ensure targeted monitoring programmes enable management to mitigate risk and protect people and food sources. The first isolate in the CICCM, *Cuspidothrix issatschenkoi*, produced a neurotoxin. This was a new species to New Zealand and the first report of an anatoxin-a producing species in the Southern Hemisphere. A novel anatoxin-a biosynthetic precursor has been identified and the strain used for international research on the effect of nitrogen on anatoxin-a production. Benthic cyanobacteria isolated from a small eutrophic Canterbury lake produced a diverse range of the neurotoxic saxitoxins (STX) and its congeners. STXs cause paralytic shellfish poisoning in humans, which is potentially fatal. Recent studies using isolate CAWBG524 showed a significant shift in toxin production through growth phases, and provided new data on STX production.

Use of molecular tools to determine whether species are recent bioinvasives

Multi-gene phylogenetic approaches bring an understanding of the biogeographic origin of bloom forming species. This approach was used to explore whether a recent identification of the toxic *Cylindrospermopsis raciborskii* in Waikato lakes was due to a new incursion. Phylogenetic analysis showed that six isolates in the CICCM were closely related to strains from South America, suggesting this was a response to environmental degradation of the lakes.

Protecting humans and animals from cyanotoxins

Dog deaths (>100) at rivers across New Zealand in the last decade have been linked to ingestion of cyanobacterial mats. Two toxin-producing species have been isolated, *Phormidium autumnale* (which produces anatoxins) and *Planktothrix* sp. (which produces microcystins). Multiple strains are maintained within the collection. Establishing this link between benthic cyanobacteria and dog deaths, and the identification of the toxic species, has led to development of monitoring programmes in risk areas, with warning signs and closures of water bodies used to reduce poisoning events. The identified toxins are also toxic to humans.

Up-to-date taxonomic knowledge and international links critical to identifying invasive marine species

Research background

The nature of New Zealand's marine environment and its high biodiversity makes managing marine biosecurity risks challenging. The Marine Invasives Taxonomic Service (MITS) is funded by MPI and delivered by, and based at, NIWA in Wellington. Active taxonomists are generally in the best position to identify samples, supported by collections and databases. This facility ensures access to expert taxonomists (both within New Zealand and internationally) who deliver consistent, timely, and accurate identification and reporting services. The overall pool of expert taxonomists is limited in New Zealand and overseas.

MITS provides a centralised identification service for a large number of marine samples from MPI's marine biosecurity programmes, including material from port surveys, vessel biofouling, surveillance, and material intercepted material at the 'border' by MPI Quarantine Officers or found by members of the public.

Commercial and Environmental Problem
To detect invasive species, knowledge of the marine organisms beyond our shores is obviously important, and we must be able to distinguish between exotic species and rare or undescribed native species. Exotic species identified by MITS come from all around the world. Many of the specimens found on vessel hulls come from as far afield as the Persian Gulf, California, and the Caribbean. Non-native species from port surveys generally originate from the Australasian region.

Example: Application of taxonomy in limiting the spread of Mediterranean fanworm
A single specimen of the invasive fouling species *Sabella spallanzanii*, the Mediterranean fanworm, collected in 2008 during routine surveillance of Lyttelton Harbour, was identified quickly and accurately because reference specimens obtained in advance from Australia were held in the NIWA collections. *Sabella spallanzanii* was already a notifiable organism under the New Zealand Biosecurity Act. A major government-funded effort was launched to eradicate this economically significant pest species from Lyttelton and looked like succeeding there, thanks to the early recognition, before a second population of what proved to be more numerous and dispersed worms was detected by NIWA in Auckland in 2009 where it is now established. Taxonomy and polychaete biology skills are required to enable limiting the spread of the worm elsewhere, and to distinguish new occurrences from native species, and assessing reproductive readiness.

National New Zealand Flax Collection: sustaining traditional cultivars used by Māori weavers and enhancing understanding of their uses and origins

Background
Manaaki Whenua is kaitiaki of a collection of traditional weaving varieties of harakeke (New Zealand flax, *Phormium* spp.), many donated by Rene Orchiston of Gisborne. The 50 harakeke in the Orchiston Collection were selected long ago from natural stands and cultivated by Māori weavers for their special leaf and fibre properties. There are varieties especially suited to making kete (baskets), whāriki (mats), piupiu (skirts) and cloaks. Many have disappeared from the places where they were originally collected.

Research
Manaaki Whenua scientists have had a long collaboration with Māori weavers in research on the characteristics of weaving plants. In 1995, experimental plantings of traditional weaving varieties of harakeke were established at sites throughout New Zealand to find out what effect environmental conditions had on their growth and weaving qualities. Samples were assessed by weavers in 2000 and 2001. Results of this research were published in five refereed papers and disseminated through the newsletter *He Kōrero Kōrari*, along with broader information on harakeke and other weaving plants, especially tī (cabbage trees, *Cordyline* spp.).

Information on where Rene's original collections came from is mostly limited to region, and, because weavers have always gift-exchanged desirable harakeke selections, the original provenance is unclear. Researchers have long been aware that several of the harakeke within the Orchiston Collection are very similar to each other. The leaves and bushes have the same colourings and form, and the special qualities are consistent, whether for raranga or muka/whītau. They do, however, have different names and have been collected from different places. As part of the assessment of harakeke in the National Collection, and to enable screening for yellow-leaf disease, Manaaki Whenua has carried out DNA fingerprinting of all the varieties. Most of the plants in the Orchiston Collection are unique varieties, but some are either close kin (originally from the same geographical area or wild population) or vegetative clones (divisions) of the same parent plant.

Outcome
The collection is now significant and well-researched, sustained by clones being distributed throughout Aotearoa, and enables local Māori weavers to access the traditional materials required for weaving culturally significant items.

Fossil dating of New Zealand's sedimentary basins

Research
New Zealand's sedimentary basins, both on land and offshore, are important current or potential sources of oil and gas. To predict, discover, and recover such resources, it is essential to know the geological age of the prospective basin strata. Since the 1930s, New Zealand geologists have identified successions of key fossils which can be used to date basinal strata from outcrops and wells. There is now a finely divided standard New Zealand Geological Timescale, providing high-resolution dates back to Late Cretaceous time, some 100 million years. The fundamental key to success is accurate identification of age-diagnostic fossils, usually microfossils of less than 1 mm dimensions. Thus, the research is founded on the taxonomy of fossils, and mistakes in identifying key species could affect a drilling programme with major expense. This research was developed over decades by New Zealand Geological Survey, and its successor organisation, GNS Science, with contributions from consultancies, universities, and museums. New Zealand's excellent fossil succession is a Rosetta Stone for such research, complementing a few others similarly detailed internationally.

Outcome
GNS has optimised the "time lines" indicated by fossil successions in the Taranaki Basin, and has made detailed isotopic correlations with fossils in the Canterbury Basin. There is ongoing international tie-in involving both commercial (oil) companies and blue-skies science initiatives, most prominently International Ocean Discovery Programme. The IODP is particularly involved in issues of ocean basin structure, circulation, and paleoclimates.
m management of our aquatic natural heritage.

Museum exhibitions of marine specimens attract thousands of people

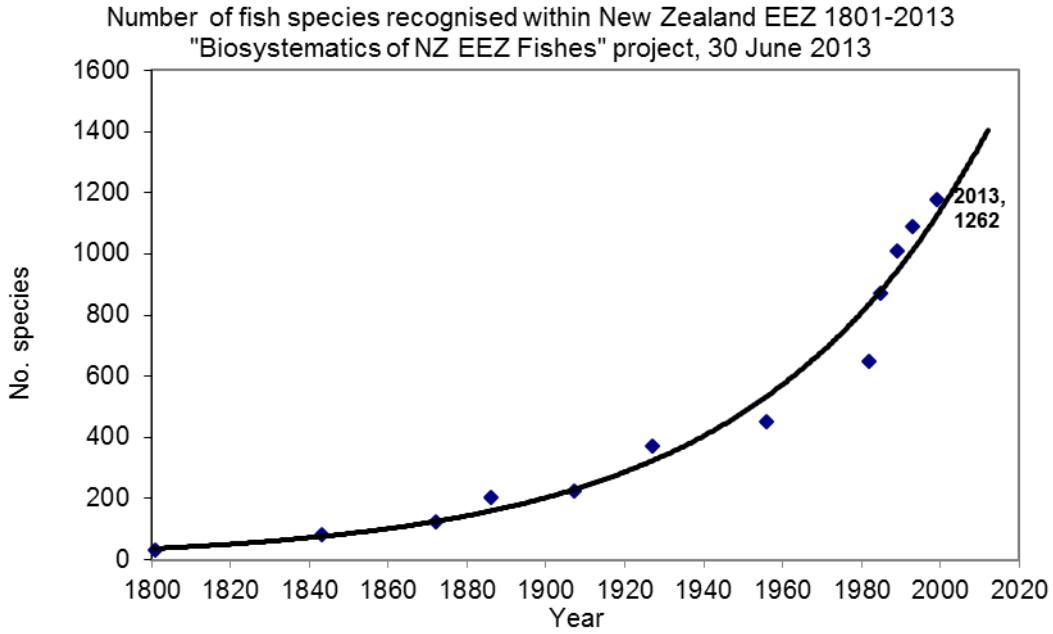
Exhibitions of marine specimens at the Museum of New Zealand Te Papa Tongarewa and the Auckland Museum attract large numbers of visitors. Recent exhibitions included two temporary exhibitions at Te Papa ('Corals – hidden beauties of the deep', and 'Deep NZ: Our underwater wilderness'), online behind-the-scenes science live video broadcasts, and the 'Moana – My Ocean' exhibition at the Auckland Museum. These exhibitions showcase the wonders of the New Zealand marine region to the wider public, and create awareness of the unique diversity we have in our region and the research that is conducted. A particular emphasis is always placed on taxonomic research, new species discoveries, and the taxonomic knowledge that is required to identify our biota. As an example, the Moana - My Ocean exhibition at the Auckland Museum, which was open to the public for four months in 2013, was visited by ca. 140,200 people. The Auckland Council Technical Support review that was commissioned by the Research, Investigations and Monitoring Unit of Auckland Council, concluded that for every $1 invested by the museum, $4.66 of social, environmental, and economic value was created[19]. Te Papa's science live broadcasts received over 700,000 viewers within a month of release.

19 http://www.aucklandcouncil.govt.nz/SiteCollectionDocuments/aboutcouncil/planspoliciespublications/technicalpublications/tr2014014sroianalysismoanaaucklandmuseumrpt.pdf

Accurate identification of New Zealand fishes underpins sustainable management and conservation of biodiversity

Research background

New Zealand has a diverse fish fauna with significant numbers of new species recognised in the last few decades, although the New Zealand fauna has been researched for more than two centuries.



Challenges

Biological research, including systematics, underpins management and conservation of our valuable and unique fish faunas, from those inhabiting our freshwaters to the outer limit of our EEZ and beyond, and to New Zealand vessels in international waters.

Benefit

Authoritative identification underpins New Zealand's Quota Management System (QMS). This system is 'species based' so identification is fundamental to its successful operation. For legal export identification to species level is required. In addition, within ecosystem-based management systems, species level information is essential, with accurate identification required for all biological and ecological survey, analyses and monitoring programmes. Correct identification of unique, endemic species enables successful conservation and ecosystem.

Historical value of collection material

Background

A selection of the original specimens collected by Banks and Solander on Cook's first journey to New Zealand are today held in the collection of the Auckland Museum, the Allan Herbarium at Landcare Research Manaaki Whenua, and at Te Papa. They only found species that were growing around the coast for the most part because they didn't get very far inland, and it was later botanical explorers who found the plants from the inland areas.

Benefit

There is huge scientific value in this collection for a number of reasons, but one of the key reasons is that this was the first European collection of plants in New Zealand. No other Europeans had collected plants here before, and all these specimens went back to England. They collected over 300 different species of plants, and this provides a reference point as to what was growing in New Zealand naturally before European colonisation. [adapted from Pat Brownsey, Te Papa blog]

Treatment of marine mammal samples as taonga

Background
The New Zealand Cetacean Tissue Archive (NZCeTA) housed at the University of Auckland is a collection of tissue samples of whales and dolphins and associated molecular sequence data. It is used widely for conservation management decisions and listings both within and outside New Zealand (New Zealand Threatened Species Listing process and IUCN listings). Many of the specimens have informed the development of the website DNA Surveillance that is used for diagnostics of illegally caught, held, or traded specimens (e.g. CITES).

Specimens in NZCeTA are collected only with the agreement of iwi and hapu with mana whenua. This differs by species and region but all are treated as taonga and the archive is open for Māori to see their taonga if they wish to do so. Many of the stranded cetaceans are named when blessed and their name is included in the archive records and follows through any reporting. Where possible, the name is included in publications to recognise the importance of the animal in our ancestry.

Outcome
The samples have been used to reveal the whakapapa of individuals within and between strandings; this is particularly so for the pilot whales that commonly mass-strand. Typically the findings are reported back to the Department of Conservation and they communicate with their local iwi or hapu; on occasion the NZCeTA staff have spoken on marae about their work.

Biodiverse: utilising collections and phylogenetic data to identify "hotspots" of endemism

Research background
With the electronic availability of large numbers of georeferenced spatial records for New Zealand plants in herbaria (e.g. Allan Herbarium) and the international development of a range of new biodiversity reporting metrics utilising spatial data as implemented in the programme called Biodiverse, Landcare Research has been able to use herbarium collections to identify important areas of endemism for conservation prioritisation, planning and management, and environmental reporting. These endemism metrics enable quantification of the area of endemism, and identification of the type of endemism (e.g. species- or generic-level endemism, and neo-or paleo-endemism).

Landcare Research has developed a "proof of concept" that utilises spatial data for 213,000 herbarium collections from the diverse fern, conifer, and flowering plant flora indigenous to New Zealand. It has also developed a cpDNA phylogeny showing relationships of all of the New Zealand genera of ferns, conifers, and flowering plants to enable phylogenetic metrics to be analysed in conjunction with the spatial data. This study has revealed new centres of endemism and confirmed previously identified "hotspots", but with more accuracy than previous studies. It shows that patterns of endemism differ depending on taxonomic rank with generic endemism well-represented in coastal and lowland northern North Island and the northern offshore Kermadec and Three Kings islands. Species endemism is concentrated in the South Island mountains such as the central Otago plateau mountains, inland and coastal Marlborough, Arthur Range in Nelson, and Surville Cliffs in Northland.

Outcome
This research will contribute significantly to future regional and national scales of conservation as many areas and types of endemism are currently poorly protected in the Department of Conservation estate. This study highlights the need to urgently consider, as part of conservation policy, the centres and types of endemism identified, and to apply this to planning and management. The new range of metrics will enable informed and scientifically sound decisions to be made, thus enabling more targeted use of the limited conservation resources to be focused on the most important areas. There is a strong expression of interest from the Ministry for the Environment to use the metrics on endemism for environmental

biodiversity reporting. The reasons for this are that the metrics are diverse, include a genetic component, are statistically robust, can be applied locally and nationally and resolved to different spatial scales, and trends can be reported.

New Zealand Arthropod Collection (NZAC) case study: resolving undescribed species and taxonomic entities for improved conservation management

Environmental Challenge

A top priority for the NZAC has been using taxonomic expertise and the collection to resolve undescribed species and other entities such as "tag names" to assist with Department of Conservation with threatened species management. Conservation management of species with uncertain status is hampered as the fundamental unit for conservation is not known. In turn this means environmental impact and biodiversity surveys are not robust when the occurrence of a species cannot be properly interpreted because it cannot be identified. This is especially critical for species that have restricted geographic ranges, exist at low densities or are susceptible to predation or environmental change. In addition to performing high quality, underpinning science to resolve these problems, it is imperative that the data and information are at the fingertips of biodiversity managers.

An example of this challenge is the threatened, geographically restricted and poorly known species from the beetle genus *Syrphetode*s. This genus includes species that are widespread and frequently observed in ecological surveys, and species that are restricted to very small geographic areas such as isolated mountain ranges and offshore islands. A number of the undescribed entities are included in the Department of Conservation Threat Classification List.

Research and Outcome

This genus was revised, with the paper including descriptions and a key so that any end-users are able to identify any specimen of *Syrphetodes* collected. Furthermore, the newly developed "New Zealand Land invertebrates" portal[20] was used to disseminate the results of this research. This means that DOC can be confident that its Threat Classification List is up to date. The specimen data that is delivered through the "Systematics Collections Data" portal[21] means that Department of Conservation staff can directly determine the geographic range of each species, the frequency with which it has been collected, and potential rarity. For many taxonomic groups, images of the critical "type specimens" that define the species are included in the SCD data base which will also assist with identification. The DNA data collected as part of this study is available through international data bases (e.g. Genbank). These data will also help to underpin interpretation of new environmental DNA (eDNA) surveys.

Documentation of cultivated plants in New Zealand

Catalogues of plants in New Zealand

There is no catalogue of exotic cultivated plants in New Zealand, that is, plants which have not naturalised but remain as garden plants. This reflects the history of plant introductions since European colonisation of New Zealand, and that there were few restrictions on plant imports until the latter half of the 20th Century. Although MPI curates the Plants Biosecurity Index (PBI) (a list of exotic plants in New Zealand developed as a working tool when HSNO was under development to guide importation of plants under the Health Standards), there are no vouchers associated with this list. It is therefore not possible to know when a species is not on the PBI if it is genuinely a new organism to New Zealand, or one of the species 'left off' the PBI. It is also possible that the plant has been misidentified previously as present in

[20] http://nzinverts.landcareresearch.co.nz/ .
[21] https://scd.landcareresearch.co.nz/

New Zealand and actually may not have ever been here. Plants missing from the PBI are more likely to be uncommon plants – those that are less fashionable, older or more specialised and uncommon. Most plant collections and gardens in New Zealand are therefore not documented.

Implications

The proceedings of a workshop of botanical and horticultural experts in 2009 states "the PBI is incomplete and lists about 27,000 species out of perhaps as many as 40,000 exotic plant species thought to already be in New Zealand"[22]. It is therefore not possible to verify which cultivated plants are present in New Zealand. This is an issue for MPI and EPA who must determine if new incursions or proposed plant imports are already in the country. As no names on the PBI are verified by vouchers there is no evidence they are correctly identified. As a result, permission to import a plant may be granted based on a plant being incorrectly on this list; and permission to import a plant may be denied even though the species has been in New Zealand for many decades, but is not on the PBI.

This situation has been identified as not only a risk to New Zealand's biosecurity, but also putting into play very expensive legal exercises for gardeners, plant importers, councils etc. to establish whether plants are already in New Zealand or not. Managers of plant collections are aware of the huge gap in the "official" list of cultivated plants in New Zealand and the actual number and identity of cultivated plants in New Zealand. A cultivated plant herbarium collection to voucher all cultivated plants in New Zealand is an essential step to protecting theNew Zealand border as well as saving taxpayer and ratepayer money as this system necessitates working out the identify of plants in New Zealand on a case-by-case basis. Ratepayer and taxpayer funds are being spent on issues that cannot ever be proven due to the lack of specimens to verify the data.

A reference collection of vouchers would be of significant value to border biosecurity and assist with timely decision making, and be more cost effective for local and central government than the current inefficient and poorly documented situation.

There is a list of native plants in New Zealand (Flora of New Zealand series I, II & V) and a list of naturalised plants in New Zealand (Flora of New Zealand series III & IV)[23]. Native plants (ca. 2,500) are plants found naturally in New Zealand, and naturalised plants (ca. 2,600 in New Zealand) are those deliberately or accidentally introduced to New Zealand which have escaped cultivation and are able to live (survive to reproduce and their offspring reproduce) "in the wild".

Ministry for Primary Industries: The critical importance of collections and taxonomy for identifying pests and diseases in biosecurity

Background

In its submission to the Royal Society Expert Panel on Taxonomic Collections, the Ministry for Primary Industries highlight how collections and the application of taxonomy to describe and name species are vital for supporting biosecurity decisions.

Importance of taxonomic collections and expertise

- The accumulated combination of knowledge, collections, and published taxonomic descriptions have provided a comprehensive background understanding of New Zealand's flora and fauna, which has enabled New Zealand to trade internationally as a country that is known to be free of many of the world's serious pests and diseases;
- Ongoing maintenance of these resources enables change to be monitored and provides historical material for reference, including providing evidence for trade decisions in bilateral discussions with

[22] Dawson (2010).

[23] http://floraseries.landcareresearch.co.nz/pages/index.aspx .

other countries;
- These collections have been indispensable for developing the Biosecurity Organisms Register for Imported Commodities (BORIC), which provides the quarantine status of pests and pathogens and which is used every day by MPI to determine the regulatory status of intercepted organisms;
- Nationally important collections are regularly referred to by MPI to assist with identifications, and also to validate freedom; there have been numerous cases where suspect "new to New Zealand" records have been represented in collected material from previous decades;
- With the availability of new molecular-based identification methods and changes in systematics and taxonomy, MPI requires access to historical material to establish the reliability, validity, and status of identifications arising from diagnostic investigations;
- Material held in the International Collection of Micro-organisms from Plants (ICMP) is frequently used by MPI to provide positive controls in diagnostic tests for new organisms;
- The ability to add new material to collections to capture current biodiversity is required;
- Records held in the data bases associated with collections are regularly used by MPI;
- The collections provide a foundation for baseline research to improve our understanding of New Zealand's unique biogeography and the relationships of our flora and fauna with other countries. This includes providing reference materials for research projects and for diagnostic protocol development;
- Nationally important collections provide secure long-term storage for the voucher specimens on which species descriptions are based and also which represent first records of exotic organisms when they are first discovered in New Zealand.

Future change in New Zealand is inevitable, and this is likely to include climate, demographics, and the structure of primary industries. Changed climate and new production ventures will almost certainly result in the emergence of new pests and diseases, and soundly based diagnostic practice involving historical records and collections will be required to determine if these are already established in New Zealand or are new arrivals. It is essential that material held in these collections is maintained in perpetuity. Ensuring records are entered into data bases adds significant value. Labels need to be kept up to date with modern nomenclature.

By sector

Animal Biosecurity

New Zealand is at risk from serious animal diseases that are covered under international arrangements linked to MPI's Central Animal Health Laboratory at Wallaceville. MPI also oversees arrangements to manage significant risks from zoonotic and food-borne diseases. Material held in collections managed by ESR is critical to supporting prompt and accurate diagnostic process for these diseases.

Aquatic Biosecurity

Safeguarding New Zealand's aquatic environment and primary industries requires knowledge of marine and freshwater biodiversity and the identity of aquatic biosecurity threats. For these purposes, taxonomic collections are an indispensable resource. The collections held by NIWA are essential to the above, and there are resources held by other institutions such as Te Papa (e.g. freshwater organisms) that are also invaluable.

Plant Biosecurity

IPPC standards provide internationally recognised guidelines for establishing within-country status of plant pests and diseases, and these can become requirements during trade disputes under the World Trade Organisation's SPS agreement. IPPC standards cover the provision of data from credible scientifically based sources, including reputable identifications and storing information for future use. Landcare Research collections have been vital for the development of MPI's plant pest and disease collections and knowledge, and for providing background information to support biosecurity decisions on new organisms.

New Zealand would find it very challenging to hold discussions on presence or absence of pests and diseases of plants in the absence of this resource.

Appendix 9: Purpose and primary function of collection holders

Museums

	Key functions/ purpose	Legislative protection/ duty of care
Museum of New Zealand Te Papa Tongarewa	To make best use of their collections in the national interest; conduct research into matters relating to its collections; and to collect and act as an accessible national depository for collections.	Museum of New Zealand Te Papa Tongarewa Act 1992 - to develop, conserve, and house securely the collections in their care.
Auckland Museum	The recording and presentation of the history and environment of the Auckland Region, New Zealand, the South Pacific; and the advancement and promotion of cultural and scientific scholarship and research.	Auckland War Memorial Museum Act 1996 - conservation of the heritage of the Museum.
Canterbury Museum	To collect, preserve, act as a regional repository for, research, display and otherwise make available to the people of the present and the future, material and information relating to the natural and cultural heritage of New Zealanders.	Canterbury Museum Trust Board Act 1993 – to preserve material and information relating to the natural and cultural heritage of New Zealanders.
Otago Museum	To collect, preserve, act as a regional repository for, research, display and otherwise make available to the people of the present and the future, material and information relating to the natural and cultural heritage of New Zealanders.	Otago Museum Trust Board Act 1996 - to preserve material and information relating to the natural and cultural heritage of New Zealanders.
Whanganui Museum	To enhance understanding of the natural and cultural heritage of the Whanganui region and its place in the world; and to facilitate the sharing of the stories of Whanganui and its place in the world by providing exhibition, education, research and advisory programmes.	Constitution of the Whanganui Regional Museum Trust - to develop a collection by holding, collecting, preserving, documenting and managing objects of natural and cultural significance to the Whanganui region.

Crown Research Institutes

The Crown Research Institutes Act 1992 does not specifically mention their taxonomic collections, but states the purpose of operation that research undertaken by a Crown Research Institute should be undertaken for the benefit of New Zealand, and in fulfilling its purpose, operate in a financially responsible manner so that it maintains its financial viability.

Independent Research organisations

The Cawthron Institute specialises in science that supports sustainable advancement of New Zealand's primary food production and export sectors including ensuring market access. A MBIE contract (CAWX0902 "CAW Nationally Significant Database") determines the care of its biological collection of microalgae.

Universities

The Education Act 1989 doesn't specifically mention universities' collections or museums, but the object of the provisions of this Act relating to institutions is to give them as much independence and freedom to make academic, operational, and management decisions as is consistent with the nature of the services they provide, the efficient use of national resources, the national interest, and the demands of

accountability. Nevertheless, the object of provisions relating to tertiary education is to foster and develop a tertiary education system that fosters, in ways that are consistent with the efficient use of national resources, high-quality learning and research outcomes, equity of access, and innovation; and their research and teaching are to be closely interdependent and most of their teaching is done by people who are active in advancing knowledge.

Cross-cutting legislation and policy with impacts on collections

The Protected Objects Act 1975 protects the contents of collections in terms of prohibiting and preventing the illicit import, export, and transfer of ownership of cultural property, although doesn't cover their care within New Zealand.

A category of "Heritage Assets" has been defined by Treasury on valuing intangible assets, which are used for financial accounting standards: "*Heritage and cultural assets are those assets that are held for the duration of their physical lives because of their unique cultural, historical, geographical, scientific, and/or environmental attributes. They assist holders of the assets to meet their objectives in regard to exhibition, education, research and preservation, all of which are directed at providing a cultural service to the community".* While New Zealand's biological taxonomic collections meet the definition of Cultural and Heritage Assets for financial reporting purposes, there are no specific guidelines provided for treatment of biological collections, or their use in providing economic and environmental services in addition to cultural services, and that there is variable treatment across collection holders in valuing their collections.

Appendix 10: Approaches to taxonomic collections overseas

The following section has been compiled from online resources, including Te Papa's report on a national biodiversity portal for New Zealand[24]:

1. Australia

Collections
CSIRO (Commonwealth Scientific and Industrial Research Organisation) has seven biological collections of national significance (herbaria, terrestrial invertebrates, fish, wildlife, algae, tree seed centre, and soil) and a large number of smaller collections including many microbial collections. Over the past decade these collections have been managed in a distributed way in association with the specific research projects. As a consequence, the resources to the collections have diminished in the face of declining appropriation (core) funding to CSIRO. CSIRO has recently restructured to bring together all its major facilities and collections into a new investment stream that will enable it to highlight to Government CSIRO's role in providing national facilities to the nation[25]. The research director is an evolutionary biologist rather than a collections' specialist and is experienced in attracting funds from a wide range of investors. This new structure is intended to enable a better allocation of resources across the collections including new key appointments. Staff are still expected to deliver some outcomes to portfolios outside the collections area.

In Australia, state museums and botanical gardens also maintain collections of biological specimens. There are two groups that have been established to assist with the coordination of collections in Australia - the Council of Heads of Australian Faunal Collections (CHAFC)[26] (a body representing Australia's publicly accessible zoological and paleontological collections, primarily within the jurisdiction of regional, state and territory, and commonwealth governments), and the Council of Heads of Australasian Herbaria (CHAH) [27] (comprising those administratively responsible for the major Australian and New Zealand Herbaria with the aim of promoting all matters of interest to herbaria in Australasia).

Research funding
The Australian Biological Resources Study (ABRS) is a programme within Parks Australia Division of the Department of the Environment, addressing the documentation of the Australian biota, its distribution and the provision of information about the biota to end users[28]. The ABRS National Taxonomy Research Grant Programme (NTRGP) is the only programme in Australia that supports research into taxonomy. It provides grants for research projects where the primary aim is to undertake taxonomic research on the Australian biota or to develop products that aid in the dissemination of taxonomic information. The programme also supports projects that build Australian taxonomic capacity. Postdoctoral Fellows, training and/or recruitment of taxonomists, especially in critical taxonomic groups, and student travel grants are supported. Co-funding is the method by which ABRS encourages an increase in funding for taxonomic research.

Online data access
CSIRO has also provided the national leadership in the development of *Atlas of Living Australia*[29] – a collaboration between CSIRO, the Australian Government, and Australia's museums. This national facility provides online access to Australia's biodiversity data. The Atlas of Living Australia contains information

[24] Waugh *et al.* (2013).
[25] http://www.csiro.au/en/Research/Collections.
[26] http://chafc.org.au/.
[27] http://www.anbg.gov.au/chah/.
[28] http://www.environment.gov.au/science/abrs.
[29] www.ala.org.au.

on all the known species in Australia aggregated from a wide range of data providers: museums, herbaria, community groups, government departments, individuals and universities. It contains more than fifty million occurrence records, based on specimens, field observations and surveys (from collections from a variety of institutions across the country including Federal and State government departments and NGOs, such as Birds Australia). These records are enriched by additional information including molecular data, photographs, maps, sound recordings and literature. The Atlas provides mapping and analysis tools, allowing users to explore the information in new ways. The Atlas of Living Australia was launched in 2008 with funding from the Australian government and in-kind contributions from partners. Development and administration is undertaken by CSIRO. A goal of the Atlas has been to develop the informatics and data management required to provide online access to biodiversity information, including new analytical tools and data quality checks.

The ALA has been working to enable the software it has developed to be reused by other countries and thematic nodes as a platform for implementing data portals. The GBIF Work Programme 2014-2016 includes activities to provide support for project coordination, documentation, training and helpdesk activities to facilitate this work. Four European nodes have decided to reuse the Atlas of Living Australia software for the development of their national biodiversity portals (Spain, France, Portugal, Scotland), and a number of their countries are exploring options.

Australasian connections

New Zealand's links across the Tasman are particularly strong and important. There are Australasian networks such as the Council of Heads of Australasian Herbaria (CHAH) and the Australasian Systematic Botany Society (ASBS), and through these networks, collaborative projects such as the Australasian Virtual Herbarium are currently being developed in collaboration with the Atlas of Living Australia. The Australasian biodiversity community is currently working collectively to develop a Decadal Plan, Biodiversity Science in Australasia 2015 – 2025, coordinated by CHAH, CHAFC, ASBS, and the Society of Australian Systematic Biologists.

2. Canada

Collections

Canadian universities, federal and local government institutions mainly hold biological collections. The Canadian national museum - Canadian Museum of Nature - is a crown corporation, mainly government funded and is a member of the Alliance of Natural History Museums of Canada[30]. In total, 52 university, 26 federal government, 20 other government and 22 other institutions holding collections responded to a survey carried out in 2009[31].

Research Funding

Research funding for taxonomy had been in decline in Canada from 1980 to 2007 and it seemed possible that taxonomy might cease to exist by 2020[32]. In May 2009, the Government of Canada, through the Minister of Canadian Heritage, asked the Council of Canadian Academies to appoint an expert panel to conduct an assessment of the state and trends of biodiversity science in Canada, and whether the country was equipped to understand the challenges of national biodiversity resources, to examine the contribution of molecular techniques and traditional taxonomy, as well as capabilities and gaps[33].

The Council states in the report:

> "*Viewed from a needs perspective, Canada's heavy involvement in the harvest of natural resources means that strong taxonomy has high strategic relevance to Canada's economic well-being, its status*

[30] http://www.naturalhistorymuseums.ca/index_e.htm.
[31] Expert Panel on Biodiversity Science (2010).
[32] Packer *et al*. (2009).
[33] Expert Panel on Biodiversity Science (2010).

as a responsible world citizen, and the protection of its natural resources."

The analysis of the Canadian situation has many parallels with the New Zealand situation. A recent report that attempted to assess the status of Canadian ecosystems observed that 'long-term, standardized, spatially complete, and readily accessible monitoring information, complemented by ecosystem research, provides the most useful findings for policy-relevant assessments of status and trends. The lack of this type of information in many areas has hindered development of this assessment'[34].

Subsequent Canadian actions have apparently made financial assistance to taxonomists available through Natural Sciences and Engineering Research Council of Canada funds (NSERC)[35] associated with DNA barcoding and have increased the number of people in training[36].

Online data access
The Expert Panel on Biodiversity Science (2010) noted that Canada currently has limited and poorly supported efforts in place to digitise information held in its collections. It states that Canada lacks a clear repository for biodiversity data that is built around common standards. They noted that data that have not been digitised are at risk of being lost, such as through the retirement of researchers. The report also noted that Canada is not fully engaged in the global effort to develop and exchange biodiversity data, which it attributed to a lack of funding support and strong government policy leadership, and the culture of taxonomic research. It recommended online open access to taxonomic data. Canada is actively developing their Canadian Biodiversity Information Facility site.

3. European Union

Online data access
There does not seem to be much central funding of taxonomic research in the EEC. Nevertheless, support goes into international databasing initiatives. For example, many jurisdictions in Europe host nodes for the Global Biodiversity Information Facility (GBIF), a data sharing initiative, thus providing access to their nation's biodiversity data by linking globally to shared independent digitised databases. Funding is usually governmental, sometimes with co-funders. For example, DanBIF, the Danish node of GBIF, was established through collaboration between the University of Copenhagen and the Danish Natural Science Research Council and NLBIF, the Dutch node of GBIF, was funded by the Ministry of Education, Culture and Science, University of Amsterdam and Netherlands Organisation for Scientific Research. In a few cases tools to analyse and model biodiversity data are also supported on these national web portals (Sweden and Norway). However, the recent establishment of LifeWatch, a collaborative project between Hungary, Italy, the Netherlands, Romania and Spain, promises to provide analytical and modelling tools for available biodiversity data as well as linking researchers and enabling them to share data. In addition, LifeWatch aims to connect to policy-makers, entrepreneurs, students and the general public[37]. The first services of LifeWatch are planned for 2013 with full operation reached by 2016.

Training
Europe has focused on developing networks of expertise so that limited taxonomic resources can be shared. The EU previously funded EDIT (European Distributed Institute for Taxonomy), but, more recently DEST (Distributed European School of Taxonomy) has been established under the umbrella of the Consortium of European Taxonomic Facilities (CETAF)[38]. CETAF is the only European network that is devoted to promoting taxonomic research and collections-based activities, and is funded by its member institutions. The major aim of DEST is to transfer knowledge between current and future generations of

[34] Federal, Provincial and Territorial Governments of Canada (2010).
[35] http://www.nserc-crsng.gc.ca/index_eng.asp.
[36] Packer *et al*. (2009).
[37] http://www.lifewatch.be/ .
[38] http://www.cetaf.org/.

taxonomists by providing high quality education, running a series of intensive post-graduate courses (involving ca. 100 providers from 60 institutions) that are available to students enrolled at tertiary institutions across Europe and also in other parts of the world.

Infrastructure support
Another initiative is SYNTHESYS[39], the European Union-funded Integrated Activities grant. This four-year project, which began in September 2013, comprises 20 European natural history museums, universities and botanic gardens, and research organisations. It aims to create an integrated European infrastructure for researchers in the natural sciences. SYNTHESYS is split into three activities: Access, Networking, and Joint Research Activities.

The SYNTHESYS Networking Activities (NAs) form an integrated package directed to supporting and developing the natural history infrastructure in Europe. The focus of this initiative is to create an integrated European resource, bringing together the biological and geological collections held by major natural history museums and other institutions. The greater integration that will result from these activities is directed to enhancing the experience of users, and to raise awareness of best practice in collection management by offering guidelines for the care, storage, and conservation of collections, with the aim of increased adoption of common standards and protocols.

4. United Kingdom

Ongoing policy dilemmas
In the United Kingdom, the House of Lords undertook a follow up investigation into the decline in taxonomy[40]. With apparent inaction from the main UK funding bodies a further study of capability was undertaken[41] alongside another paper proposing a national strategy for biosystematics and associated biological collections[42]. In their review of the United Kingdom's taxonomy and systematic, Boxshall and Self (2011) observed that 'The continuing improvement and updating of digital resources is essential but difficult to fund. Identifying a mechanism for the long-term funding of these systems after they have been assimilated into the infrastructure remains a strategic priority.' Godfray *et al.* (2011) proposed a national strategy in taxonomy and systematics, recommending the development of a Taxonomic Co-ordination Committee, one of whose roles would be to foster links between scientists and user communities, to define digitisation and web priorities within the United Kingdom and ensure interoperability with international initiatives.

This approach has the following key elements of relevance to New Zealand:

- The strategy needs to be adaptive, responding to changes in the funding landscape, the science itself, and the needs of taxonomists and their user communities
- The strategy needs to be developed in consultation with the taxonomic community, and the main users of taxonomy
- A national committee should be established to coordinate, develop and maintain a dynamic strategy
- A review of the role and significance of collections should underpin the strategy
- The need to define digitisation and web priorities given the impossibility of undertaking complete digital inventories
- Recognise the emergence of molecular-based technologies especially for some groups of organisms
- The need to develop appropriate tools for users

[39] http://www.synthesys.info/.
[40] Anon (2008).
[41] Boxshall & Self (2011).
[42] Godfray *et al.* (2011); Anon (2008)

- The importance of volunteer or citizen scientists in undertaking taxonomy-related activities
- The development and prioritisation of research programmes that have elements of:
  i. Major digitisation campaigns
  ii. Establishment of web-based taxonomies of significant taxa
  iii. Completion of significant taxonomic resources (such as identification guides)
  iv. Assembling key branches (phylogenies) of the Tree of Life
  v. Bar-coding campaigns
  vi. Taxonomic inventories
  vii. Micropaleontological resources to reconstruct climate change

5. United States of America

Collections

There are more than 1,600 biological collections (biocollections) in the United States with more than one billion specimens amassed, annotated, and curated in those collections. Recognising the value of biocollections for research, education, and society, the biocollections community coalesced in 2010 to develop A Strategic Plan for Establishing a Network Integrated Biocollections Alliance (NIBA), with a "strong and urgent call for an aggressive, coordinated, large-scale, and sustained effort to digitise the nation's biocollections in order to mobilize their data through the Internet". In 2012, the biocollections community recognised a need for an implementation plan that explicitly identified the corresponding actions, timelines, and milestones required to achieve the goals of the Strategic Plan. Key objectives of the strategic plan are: (1) Digitise data from all US biological collections, large and small, and integrate these in a Web-accessible interface using shared standards and formats; (2) develop new Web interfaces, visualization and analysis tools, data mining, georeferencing processes and make all available for using and improving NIBA resources; (3) create real-time upgrades of biological data and prevent the future occurrence of non-accessible collection data through the use of tools, training, and infrastructure[43].

In 2014 the Network Integrated Biocollections Alliance was launched with the Vision statement: "*The Network Integrated Biocollections Alliance will develop an inclusive, vibrant, partnership of U.S. biological collections that collectively will document the nation's biodiversity resources and create a dynamic electronic resource that will serve the country's needs in answering critical questions about the environment, human health, biosecurity, commerce, and the biological sciences"*. This initiative is a partnership between the Natural Science Collections Alliance, the American Institute of Biological Sciences and the Society for the Preservation of Natural History Collections, and is being supported by a five-year grant from the National Science Foundation.

A recent White House report highlighted the advantages of applying informatic technologies to existing stores of biodiversity data[44]. The report also emphasised the importance of the role of the Federal government, through its National Science and Technology Council and White House Office of Science and Technology Policy, in developing such a system.

Research funding

The intersection of taxonomy, genetics and functional biology is the foundation for the National Science Foundation (NSF) in the US's programme 'Dimensions of Biodiversity' and is highlighted in the report in the US from the President's Council of Advisors on Science and Technology '*Sustaining Environmental Capital: Protecting Society and the Economy'*[44].

Among current National Science Foundation (NSF) programmes are the following. "Advances in Biological Informatics (ABI)" seeks to encourage new approaches to the analysis and dissemination of biological

[43] http://www.aibs.org/public-policy/NIBA_Implementation_Plan.pdf.
[44] President's Council of Advisors on Science and Technology (2011).

knowledge for the benefit of both the scientific community and the broader public. The ABI programme is especially interested in the development of informatics tools and resources that have the potential to advance or transform research in biology supported by the Directorate for Biological Sciences at the National Science Foundation. The ABI programme accepts three major types of proposals: Innovation awards that seek to pioneer new approaches to the application of informatics to biological problems; development awards that seek to provide robust cyberinfrastructure that will enable transformative biological research; and sustaining awards that seek to support ongoing operations and maintenance of existing cyberinfrastructure that is critical for continued advancement of priority biological research.

The NSF programme "Collections in support of biological research" provides funds: 1) for improvements to secure and organise collections that are significant to the NSF BIO-funded research community; 2) to secure collections-related data for sustained, accurate, and efficient accessibility to the biological research community; and 3) to transfer ownership of collections. The CSBR programme provides for enhancements that secure and improve existing collections, improve the accessibility of digitised specimen-related data, and develop better methods for specimen curation and collection management. Requests should demonstrate a clear and urgent need to secure the collection, and the proposed activities should address that need. Biological collections supported include established living stock/culture collections, vouchered non-living natural history collections, and jointly-curated ancillary collections such as preserved tissues and DNA libraries.

"Genealogy of Life" (NSF programme) seeks research on the comprehensive understanding of life and how and why it changes over time depends on knowledge of the phylogeny (evolutionary relationships) of living and extinct organisms. The goals of the programme are to resolve the phylogenetic history of all life's diverse forms and to integrate this genealogical architecture with underlying organismal and environmental data. The ultimate vision of this programme is an open access, comprehensive Genealogy of Life that will provide the comparative framework necessary for testing questions in systematics, evolutionary biology, ecology, and other fields.

From mid-2011 the National Science Foundation funded a programme entitled "Advancing Digitisation of Biological Collections (ADBC)". This began developing a national resource called Integrated Digitised Biocollections (iDigBio), which is actively supporting the digitisation of biological collections. The long-term goal of iDigBio is to develop a permanent cloud computing infrastructure linking United States of America's biological data into a single web interface, including search and analytical tools.

6. ***International initiatives***

The objectives of the Convention on Biological Diversity (CBD), are the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies[45]. The secretariat of CBD is institutionally linked to the United Nations Environment Programme, its host institution, and has been located in Montreal, Canada since 1996. Its head, the Executive Secretary, is appointed by the Secretary-General of the United Nations in consultation with the Conference of Parties through its Bureau. A cross-cutting issue for the CBD is the taxonomic impediment to biodiversity conservation. In 1998 the Global Taxonomic Initiative (GTI) was endorsed to remove or reduce the impediment. The GTI programme[46] has a number of operational objectives related to: taxonomic needs assessment, building and maintaining human resources, capacity building, infrastructure for access to taxonomic information, etc. Although New Zealand is a ratifying party to the CBD and the Cartagena Protocol, it reported in 2005[47] that no specific initiatives had been undertaken in relation to the GTI. So far, Canada, the United Kingdom, and the Central African Republic

[45] https://www.cbd.int/.
[46] https://www.cbd.int/gti/.
[47] MFAT (2005).

have prepared needs assessments[48]. The Panel notes that the USA is the only developed country not party to the CBD.

The Global Biodiversity Information Facility (GBIF) was formed as a multilateral, intergovernmental agreement to share the vast quantities of global biodiversity data freely and openly on the internet[49]. New Zealand was a founding member and there are now over 60 countries involved and over 500 million records currently available. The New Zealand node[50] is managed by a staff member of Landcare Research. A similar enterprise for the marine environment was Ocean Biogeographic Information System (OBIS) which is a formal collaboration between GBIF and the Intergovernmental Oceanographic Commission of UNESCO, bringing further rationalisation to various attempts to make data more widely available. NIWA operates and updates the Southwest Pacific Region node for OBIS currently funded by the Environmental Information Portfolio using Core Funding[51].

Another series of related online initiatives are designed to give authoritative information about the validity of species names. These initiatives were begun independently, sponsored by various communities of interested taxonomists. Currently, the Integrated Taxonomic Information Systems (ITIS) and Species 2000 are combined under Catalogue of Life (CoL)[52]. The Catalogue of Life is evolving to provide an effective partner to six global biodiversity programmes (through the *Indexing for Life* European e-Infrastructure project, 2010-2013), creating an ecosystem of services. The Catalogue is able to support the needs of these partner programmes in establishing validated taxonomy, and moreover share a variety of related services amongst all. The World Register of Marine Species (WoRMS) is also collaborating with the Catalogue of Life team.

IPBES (Intergovernmental Platform on Biodiversity and Ecosystem Services) was established in April 2012, as an independent intergovernmental body for assessing the state of the planet's biodiversity, its ecosystems and the essential services they provide to society. IPBES aims to strengthen capacity for the effective use of science in decision-making at all levels, and capacity in underpinning disciplines necessary for this work (including taxonomy). IPBES is open to all member countries of the United Nations. New Zealand is one of 124 countries in IPBES, and has expert advisors on several of the Task Forces and working groups. IPBES provides a mechanism recognised by both the scientific and policy communities to synthesise, review, assess and critically evaluate relevant information and knowledge generated worldwide by governments, academia, scientific organisations, non-governmental organisations, and indigenous communities. This involves a credible group of experts in conducting assessments of such information and knowledge in a transparent way.

[48] https://www.cbd.int/gti/needs.shtml .
[49] http://www.gbif.org/.
[50] http://www.gbif.org/country/NZ/participation.
[51] http://iobis.org/mapper/ (Kevin Mackay, NIWA, personal communication).
[52] http://www.catalogueoflife.org/.

Appendix 11: Global taxonomic effort

Some recent papers[53], in the context of answering the question "how many species remain to be described globally", purport to show that:

1. More taxonomists are describing species than ever before;
2. The rate of species discovery per 'taxonomist' is falling.

They used the decline in rate of species discovery to estimate the number of missing species.

Their conclusions have become the subject of heated debate[54] because the results imply there is not a taxonomic crisis. The reaction of individual taxonomists has been indignant given their individual circumstances. For example, Quentin Wheeler (2014) of Arizona State University, has witnessed the steady haemorrhaging of prestige, funding, and positions from taxonomy for more than three decades. He finds that advertisements seeking to hire taxonomists to do taxonomy and grants to do taxonomy for its own sake are essentially non-existent. Bebber *et al.* (2014) and Mora *et al*. (2013) critique the analysis of Joppa *et al.* (2011) and Costello *et al.* (2013). Whether conclusions can be justifiably drawn from analyses of the apparent rate of new species discovery, and some notion of the taxonomic work force, depends on several issues. First, it is important to know where, in the phase of discovery, a taxon of interest is currently; second, synonyms that exist unquestioned in some data bases need to be acknowledged as sources of overestimation of numbers of species[55]; and, third, there needs to be recognition that the number of full time professional taxonomists is not accurately represented by the total authorship of many taxonomic papers[56].

The most relevant aspect of this debate, to our report, is the contention that there are more taxonomists than there have ever been. It is true that the numbers of taxonomists are decreasing in some institutions of the countries that formerly led in taxonomy. Nevertheless, in Asia and South America, numbers appear to be increasing[57]. The contention that taxonomists are increasing 'exponentially'[58] is challenged by Bebber *et al.* (2014) who analyse the phenomenon of 'author inflation". That is, they found a tendency, with time, for the number of authors on a paper to increase in several research areas, including the taxonomy of flowering plants. They point out that the authors of papers are not necessarily the authority for the species description and, over the period from 1970 – 2011, the number of authors linked with species descriptions increased three-fold. At the same time the average number of species described per author decreased. They argue that these data show that, for flowering plants, there has been a nearly constant rate of description of species over the 40-year period and that global taxonomic capacity has remained largely unchanged but, like other branches of science, authorship has increased as students, junior staff, laboratory assistants and technical staff are included as authors on papers as well as with an increase in collaborative science.

Much of the above debate seemed to be caused by the extent to which data were aggregated, whether the limitations of their data were fully acknowledged, whether authors were analysing taxa that are in mature or early phases of species discovery, and whether or not the controversial ideas were being expressed by someone perceived to have a good grasp of the total systematics / taxonomic enterprise.

The take-home message for New Zealand has the following parts:

1. The local context is the most relevant;

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[53] Joppa *et al.* (2011); Costello *et al*. (2012), (2013).
[54] Mora *et al*. (2013); de Carvalho *et al*. (2014); Bebber *et al*. (2014); Wheeler (2014).
[55] Löbl & Leschen (2014).
[56] Bebber *et al*. (2014).
[57] Costello *et al*. (2013).
[58] Joppa *et al*. (2011).

2. It is important to know the state of knowledge of our flora and fauna including how many taxa are in the very earliest stages of discovery;
3. The relevant measures of a healthy, internationally connected, professional employed workforce in New Zealand include a basic number of professional taxonomists who have enough funded research time to be regular contributors to new species discovery as well as contributors to knowledge of the evolution and relationships (systematics) of the New Zealand flora and fauna with the rest of the world.

Appendix 12: Application of new technologies and tools

Internationally, there is increasing attention to the opportunities provided by new developments in bioinformatics and cyberinfrastructure for collections-based research and the wider applications for biodiversity data[59] . Examples of the application of tools that enable much greater impact from biodiversity and collections include:

Name resolution: The digitisation of biodiversity data is leading to the uncritical, widespread application of taxon names that are superfluous, ambiguous or incorrect, resulting in mismatched records and potentially inflated species numbers. The ultimate consequences of misspelled names and bad taxonomy are erroneous scientific conclusions and faulty policy decisions[60]. NZOR (see p.3) is primarily a tool for standardizing the naming and identification of the specific set of organisms known to occur in and around the New Zealand region and is a global first.

Virtual access to collections: Image scanning, macro/micro photography and Scanning Electron Microscopy of critical specimens enables images to be made available online (for example at Te Papa, NIWA, and Landcare Research) enabling much wider access than is possible through visits to the physical collections, and also reduces the risk of damage and impacts of handling on vulnerable material. In addition, some disciplines are advocating for the use of "high quality, digital, multi-focal video images" of type material, and to make these openly available online. By making critical information accessible to researchers, it is hoped to speed up stages that are problematic for exchange of ideas and information within the international taxonomic community[61].

DNA sequencing techniques including high-throughput DNA sequencing, real-time sequencing techniques, environmental DNA: The use of environmental samples (eDNA) for monitoring, with applications particularly in conservation and biosecurity, is gaining traction worldwide and is a significant project within the Biological Heritage National Science Challenge. However, the identification of DNA sequences derived from environmental samples depends crucially on reliable reference DNA sequence databases and their voucher specimens deposited in biological collections. Thomsen & Willerslev (2015) observe "New generations of powerful technologies such as novel real-time sequencing techniques or nanopore-based sequencing, carbon nanotube chips, and real-time laser transmission spectroscopy are awaiting full trial of their promising potential in eDNA approaches. It is expected that the use of eDNA in conservation and biological monitoring will move from single-marker analyses of species or communities to meta-genomic surveys of entire ecosystems for predicting spatial and temporary biodiversity patterns."

New taxonomic protocols and integrative taxonomy: Integrated systematics research is currently the 'gold standard' involving analysis of as many different data sources as possible to delimit and revise species, including different types of morphological, molecular and other data. These approaches also incorporate the development of new taxonomic protocols, new methods to deal with analyses of character states and congruence, evolutionary states, the development of modular software for species delimitation, description, geographical modelling and mapping, and dynamic online publishing[62].

Remote and automatic identification services: The use of online digital microscopy for identification of specimens, with live consultation possible between researchers in different physical locations at a national or international scale (For example, MPI Marine Invasives Taxonomic Service run by NIWA, MPI and CSIRO), offers great potential. Automatic identification, applied statistics and machine learning are

[59] Wen *et al.* (2015); Costello *et al.* (2015)
[60] Bortolus (2008); Boyle *et al*. (2013).
[61] Abebe *et al*. (2014).
[62] Padial *et al*. (2010).

all areas of future development (e.g. plant identification with computing neural networks[63]).

Digital delivery systems: There are many approaches and tools, including portals and apps, to allow greater access to identification tools, information about local or regional biodiversity, as well as tools for community resource management and citizen science initiatives[64]. There is also a revolution underway in the delivery of scholarly and popular accounts of biodiversity research, for example in electronic publishing of floras, taxonomic revisions, checklists, guidebooks and interactive keys. Although databases and virtual access cannot substitute for the physical collections and related taxonomic research, there are very important opportunities that "cyberinfrastructure" can provide and adoption of a range of technologies would enable much better value from the existing network of collections and data[65].

[63] http://arxiv.org/abs/1506.08425.
[64] For example, A Nation of Curious Minds (http://www.curiousminds.nz/) and Nature Watch (http://naturewatch.org.nz/).
[65] Costello *et al*. (2015).

Appendix 13: References

Anon (2008) Systematics and taxonomy: follow up. London, House of Lords, 330 pp.

Abebe E., Mekete T. & Decraemer W. (2014) E-typing for nematodes: an assessment of type specimen use by nematde taxonomists with a summary of types deposited in the Smithsonian Nematode Collections. Nematology 16: 879–888.

Bebber D.P., Wood J.R.I., Barker C. & Scotland R.W. (2014) Author inflation masks global capacity for species discovery in flowering plants. New Phytologist 201: 700–706.

Bortolus A. (2008) Error cascades in the biological sciences: the unwanted consequences of using bad taxonomy in ecology. Ambio 37: 114–118.

Boxshall G. & Self D. (2011) UK Taxonomy and Systematics Review 2010. Report to the Natural Environment Research Council. 37 pp.

Boyle B., Hopkins N., Lu Z., Raygoza Garay J.A., Mozzherin D., Rees T., Matasci N., Narro M.L., Piel W.H., Mckay S.J., Lowry S., Freeland C., Peet R.K. & Enquist B.J. (2013) The taxonomic name resolution service: an online tool for automated standardisation of plant names. BMC Bioinformatics 2013: 14:16.

Brownsey P.J. & Baker A.N. (1983) The New Zealand biota: what do we know after 200 years?: contributions to a symposium organised by the Systematics Association of New Zealand, 25-26 August, 1980 at Victoria University, Wellington/edited by Brownsey P.J. & Baker A.N.

Conway Powell Consulting Ltd (1994) Biosystematics – New Zealand's Current Capabilities and Future Needs. Analysis of two questionnaire surveys carried out in 1994 for the Ministry of Research, Science and Technology. December 1994.

Costello M.J., Coll M., Danovaro R., Halpin P., Ojaveer H. & Miloslavich P. (2010) A census of marine biodiversity knowledge, resources, and future challenges. PLOS ONE 5(8): 1–15.

Costello M.J., Wilson S. & Houlding B. (2012) Predicting total global species richness using rates of species description and estimates of taxonomic effort. Systematic Biology 61(5): 871–883.

Costello M.J., May R.M. & Stork N.E. (2013) Can we name earth's species before they go extinct? Science 339: 413–416.

Costello M.J., Vanhoorne B. & Appeltans W. (2015) Conservation of biodiversity through taxonomy, data publication, and collaborative infrastructures. Conservation Biology 29: 1094–1099.

Crampton J.S. & Cooper R. A. (2010) The state of paleontology in New Zealand. Palaeontologia Electronica 13 (2): 4E:9p; http://palaeo-electronica.org/paleo/2010_2/commentary/zealand.htm

Dawson M. I. (2010) Documenting New Zealand's cultivated flora: "A supermarket with no stock inventory" Report from a TFBIS-funded workshop held in Wellington, New Zealand 9th September 2009. Editor: Dawson M.I., Landcare Research Version 2, 5 July 2010 http://www.landcareresearch.co.nz/publications/researchpubs/Report-documenting_New_Zealands_cultivated_flora.pdf

de Carvalho M.R., Ebach M.C. & Williams D.M. *et al.* (2014) Does counting species count as taxonomy? On misrepresenting systematics, yet again. Cladistics 30: 322–329.

de Lange P. J., Rolfe J.R., Champion P. D., Courtney S. P., Heenan P. B., Barkla J.W., Cameron E.K., Norton D.A. & Hitchmough R.A (2013) Conservation status of New Zealand indigenous vascular plants, 2012. Department of Conservation.

Deloitte (2011) MAF *Styela clava*: Economic Impact Assessment. Report to the Ministry of Agriculture and Forestry. Wellington, Deloitte, 25 pp.

Department of Conservation General Policy (2005) Effective partnerships with tangata whenua can achieve enhanced conservation of natural resources and historical and cultural heritage. Tangata whenua responsibilities to this heritage are embodied in the ethic of kaitiakitanga. Kaitiakitanga is a spiritual and environmental ethos that governs tangata whenua responsibilities for the care and protection of mauri, the dynamic life principle that underpins all heritage. Kaitiakitanga includes components of protection, guardianship, stewardship and customary use. It is exercised by tangata whenua in relation to ancestral lands, water, sites, resources and other taonga. The focus of kaitiakitanga is manaaki (care) and rahui (protection). http://www.doc.govt.nz/about-us/our-policies-and-plans/conservation-general-policy/2-treaty-of-waitangi-responsibilities/

Dodson G. (2014) Moving forward, keeping the past in front of us: Treaty settlements, conservation co-governance and communication. In Dodson G. & Papoutsaki E. (Eds.), Communication issues in Aotearoa New Zealand: A collection of research essays (pp 62-73). Auckland, New Zealand: Epress Unitec; "the conservation estate contains tāonga species and significant landscapes which enable Māori to express customary and traditional relationships in ways other lands do not (Waitangi Tribunal, 2011)."

DSIR (1989) Report of the Review Committee on Biosystematics and Ecological Science: to the Director General, Department of Scientific and Industrial Research. DSIR science activity area reviews 4, 49pp.

Expert Panel on Biodiversity Science (2010) Canadian Taxonomy: Exploring Biodiversity, Creating Opportunity. Council of Canadian Academies, 126 pp.

Faith D.P., Collen B., Ariño A., Koleff P., Guinotte J., Kerr J. & Chavan V. (2013) Bridging the biodiversity data gaps: Recommendations to meet users' data needs. Biodiversity Informatics 8: 41-58.

Federal, Provincial and Territorial Governments of Canada (2010) http://www.biodivcanada.ca/A519F000-8427-4F8C-9521-8A95AE287753%5CEN_CanadianBiodiversity_FULL.pdf

Foundation for Research, Science and Technology (1993) Nationally Significant Public Good Science Fund Databases and Collections. 22 pp.

Foundation for Research, Science and Technology (2009) Expert Panel Report Outcome-Based Investment Year-4 Review. Marine Biodiversity and Biosecurity. Contract CO1X0502. 52p. Chaired by Morgan Williams.

Frey J.K. (2009) Distinguishing range extensions from previously undocumented populations using background data from museum records. Diversity and Distributions 15: 183–187.

Godfray C., Boxshall G., Akam M., Bailey M., Baxter M., Chase M. Fortey R., Knapp S. & Maclean I. (2011) Developing a National Strategy in Taxonomy and Systematics. Report to the Natural Environment Research Council, 21 pp.

Goldson S.L., Bourdôt G.W., Brockerhoff E.G, Byrom A.E., Clout M.N., McGlone M.S., Nelson W.A., Popay A.J., Suckling D.M. & Templeton M.D. (2015) New Zealand pest management: current and future challenges, Journal of the Royal Society of New Zealand, 45:1, 31–58, doi: 10.1080/03036758.2014.1000343.

Gordon D.P. (2009) New Zealand Inventory of Biodiversity: Volume one: Kingdom Animalia: Radiata, Lophotrochozoa, Deuterostomia. Canterbury University Press, Christchurch, New Zealand.

Gordon D.P. (2010) New Zealand Inventory of Biodiversity: Volume two: Kingdom Animalia: Chaetognatha, Ecydysozoa, Ichnofossils. Canterbury University Press, Christchurch, New Zealand.

Gordon D.P. (2012) New Zealand Inventory of Biodiversity: Volume three: Kingdoms Bacteria, Protozoa, Chromistae, Plantae, Fungi. Canterbury University Press, Christchurch, New Zealand.

Gordon D.P. (2013) New Zealand's genetic diversity. *In.* Dymond J.R. (ed). Ecosystem Services in New Zealand – conditions and trends. Lincoln, New Zealand, Manaaki Whenua Press.

Graham C.H., Ferrier S., Huettman F., Moritz C. & Peterson A.T. (2004) New developments in museum-based informatics and applications in biodiversity analysis. Trends in Ecology and Evolution 19: 497–503.

House of Lords Science and Technology Committee (1992) First report, session 1991–92, Systematic biology research (HL Paper 22). London, UK.

House of Lords Science and Technology Committee (2002) Third report, session 2001–02, What on earth? The threat to the science underpinning conservation (HL Paper 118). London, UK.

House of Lords Science and Technology Committee (2008) Fifth report, session 2007–08, Systematics and taxonomy: follow-up. (HL Paper 162). London, UK.

Joppa L.N., Roberts D.L. & Pimm S.L. (2011) The population ecology and social behaviour of taxonomists. Trends in Ecology and Evolution 26(11): 551–553.

Johnson K.G., Brooks S.J., Fenberg F.B., Glover A.G., James K.E., Lister A.M., Michel E., Spencer M., Todd J.A., Valsami-Jones E., Young J.R. & Stewart J.R. (2011) Climate change and biosphere response: unlocking the collections vault. BioScience 61(2): 147–153. doi: 10.1525/bio.2011.61.2.10.

Kress W.J. (2014) Valuing Collections. Science 346 (6215): 1310.

Krishtalka, I. & Humphrey P.S. (2000) Can natural history museums capture the future? BioScience

50(7):611–617.
Lees D.C., Lack H. W., Rougerie R., Hernandez-Lopez A., Raus T. Avtzis N. D., Augustin S. & Lopez-Vaamonde C. (2011) Tracking origins of invasive herbivores through herbaria and archival DNA: the case of the horse-chestnut leaf miner. Front Ecol Environ 9(6): 322–328. doi:10.1890/100098.
Lester P.J., Brown S.D.J., Edwards E.D., Holwell G.I., Pawson S.M., Ward D.F. & Watts C.H. (2014) Critical issues facing New Zealand entomology, New Zealand Entomologist 37(1): 1–13, DOI: 10.1080/00779962.2014.861789
Löbl I. & Leschen R.A.B. (2014) Misinterpreting global species number: examples from Coleoptera. Systematic Entomology 39: 2–6.
MacDiarmid A., Thompson D., Pinkerton M. & Hume T. (2012) Scoping analysis of matters to consider when reporting on the state of marine environment. Prepared for Parliamentary Commissioner for the Environment. NIWA Client Report No: WLG2012-31, 107 pp.
McCarthy M.A. (1998) Identifying declining and threatened species with museum data. Biological Conservation 83: 9–17.
Markham K.R., Franke A., Given D.R. & Brownsey P. (1990) Historical Antarctic ozone level trends from herbarium specimen flavonoids. Bulletin de Liason du Groupe Polyphenols 15: 230–235.
MFAT (2005) Report on implementation of programme of work for the Global Taxonomy Initiative. Programme of Work for the Global Taxonomy Initiative, Annex to Decision VI/8.
Ministry for the Environment (2015) Environment Aotearoa 2015: Data to 2013. Newzealand.govt.nz .
Ministry of Business, Innovation & Employment (2014) Draft National Statement of Science Investment: 2014-2024. May 2014.
Ministry of Business, Innovation & Employment (2015) National Statement of Science Investment: 2015-2025. October 2015.
Ministry of Research, Science and Technology review (1995) Biosystematics: Issues and Options for New Zealand: a report to the Chief Scientist of the Ministry of Research, Science and Technology. Penman D.; New Zealand.
Ministry of Research, Science and Technology (2007) A more stable funding environment – 'Backbone'. Sector engagement paper. April 2007.
Mora C., Rollo A. & Tittensor D.P. (2013) Comment on "Can we name earth's species before they go extinct? Science 341: 237.
Newbold T. (2010) Applications and limitations of museum data for conservation and ecology, with particular attention to species distribution models. Progress in Physical Geography 34: 3–22.
Nimmo-Bell (2009) Economic costs of pests to New Zealand. MAF Biosecurity New Zealand Technical Paper No: 2009/31. ISBN 978-0-478-35178-1.
Nunn G.B., Cooper J., Jouventin P, Robertson C.J.R. & Robertson G.G. (1996) Evolutionary relationships among extant albatrosses (Procellariiformes: Diomedeidae) established from complete cytochrome- b gene sequences. The Auk. 113(4): 784–801.
Robertson C.J.R. & Nunn G.B. (1998) Towards a new taxonomy for albatrosses. p. 13-19. In: Robertson G. & Gales R. (eds) Albatross Biology and Conservation. Surrey Beatty & Sons, Chipping Norton, Australia.
NZIER (2005) Sea squirt alert: economic impact assessment of *Styela clava*. Report to MAF Biosecurity New Zealand. Wellington, NZIER.
Ove F. & Snijders T. (1994) Estimating the size of hidden populations using snowball sampling. Journal of Official Statistics 10(1): 53–67.
Packer L., Grixti J.C., Roughley R.E. & Hanner R. (2009) The status of taxonomy in Canada and the impact of DNA barcoding. Canadian Journal of Zoology 87: 1097–1110.
Padial J.M., Miralles A., De la Riva I. & Vences M. (2010) The integrative future of taxonomy. Frontiers in Zoology 7: 16. doi:10.1186/1742-9994-7-16.
Penman D.R. (1995) Biosystematics: Issues and Options for New Zealand. MoRST Report 41.11 + 6 pp.
Penman D.R. (1996) Biosystematics Capability and Needs Assessment for New Zealand. Issue 57, Report, Ministry of Research, Science and Technology, 50 pp.
Penman D.R. (2002) Biosystematics: Capability and needs Assessment for New Zealand – 2001/02. In: Global Taxonomy Initiative in Asia. Report and Proceedings of 1st GTI Regional Workshop in Asia, Putrajaya, Malaysia, September 2002. Research Report from the National Institute for

Environmental Studies, Japan No. 175, 2003. Edited by Shimura J.
Ponder W.F., Carter G.A., Flemons P. & Chapman R.R. (2001) Evaluation of museum collection data for use in biodiversity assessment. Conservation Biology 15: 648–657.
President's Council of Advisors on Science and Technology (2011) Sustaining Environmental Capital: Protecting Society and the Economy. Report to the President. Executive Office of the President President's Council of Advisors on Science and Technology, July 2011, 145 pp.
Proceedings of Royal Society of New Zealand (1985) Report of the Ad Hoc Committee on National Collections. Volume 113: 107-117.
Pyke G.H. & Ehrlich P.R. (2010) Biological collections and ecological/environmental research: a review, some observations and a look to the future. Biological Reviews 85: 247–266.
Review Committee on Biosystematics and Ecological Science (1989) Report of the Review Committee on Biosystematics and Ecological Science. DSIR Science Activity Area Reviews 4, 49 pp.
Ryan K. G., Burne A. & Seppelt R. D. (2009) Historical ozone concentrations and flavonoid levels in herbarium specimens of the Antarctic moss *Bryum argenteum*. Global Change Biology 15: 1694–1702. doi: 10.1111/j.1365-2486.2009.01885.x.
Schilthuizen, M., Vairappan, C.S., Slade, E.M., Mann, D.J. & Miller, J.A. (2015) Specimens as primary data: museums and 'open science'. Trends in Ecology & Evolution 30(5): 237–238.
Shaffer H.B., Fisher R.N. & Davidson C. (1998) The role of natural history collections in documenting species decline. Trends in Ecology and Evolution 13: 27–30. doi: 10.1016/ S0169-5347(97)01177-4.
Statistics New Zealand (2014) New Zealand in profile: 2014 http://www.stats.govt.nz/browse_for_stats/snapshots-of-nz/nz-in-profile-2014.aspx
Stefaniak L., Zhang H., Gittenberger A., Smith K., Holsinger K., Lin S. & Witlatch R. B. (2012) Determining the native region of the putatively invasive ascidian *Didemnum vexillum* Kott, 2002. Journal of Experimental Marine Biology and Ecology 422-423: 64–71.
SYSTANZ (1985) Biological Systematics in New Zealand. A report prepared by the Systematics Association of New Zealand (SYSTANZ) by Brownsey P. J.
Thomsen P.F. & Willerslev E. (2015) Environmental DNA – An emerging tool in conservation for monitoring past and present biodiversity. Biological Conservation 183: 4–18.
Tomizuka T., Iwatsuki K. & Miyata M. (2012) Estimation of environmental changes on shallow seawater by the use of voucher specimens of seaweeds preserved in Universities and Museums. Japanese Journal of Botany 87: 31–40.
Waitangi Tribunal (2011). Ko Aotearoa Tenei: A report into claims concerning New Zealand law and policy affecting Māori culture and identity. Volume 2 (Governmental No. 978-1-869563-01-1) (pp. 1–432). Wellington, NZ: Ministry of Justice, New Zealand Government. Retrieved from https://forms.justice.govt.nz/search/Documents/WT/wt_DOC_68356606/KoAotearoaTeneiTT2Vol2W.pdf
Ward D.F. (2012) More than just records: analysing natural history collections for biodiversity planning. PLoS ONE 7(11): e50346: 1–8.
Waugh S., Shepherd L. & Burnett A. (2013) Te Papa TFBIS Project (483) on a National Biodiversity Portal for New Zealand. User needs analysis and demonstration portal site. Final Report 19 August 2013.
Wen J., Ickert-Bond S.M., Appelhans M.S., Dorr L.J. & Funk V.J. (2015) Collections-based systematics: Opportunities and outlook for 2050. Journal of Systematics and Evolution, 53: 477–488. doi: 10.1111/jse.12181.
Whaanga H., Papa W., Wehi P. & Roa T. (2013) The use of the Maori language in species nomenclature. Journal of Marine and Island Cultures 2: 78–84.
Wheeler Q. (2014) Are reports of the death of taxonomy an exaggeration? New Phytologist 201: 370–371.
Williams P. & Timmins S. (2002) Economic impacts of weeds in New Zealand. In: Pimentel D. ed. Biological invasions, economic and environmental costs of alien plant, animal, and microbe species. London, CRC Press:175–184.

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ISBN 978-1-877317-11-8