Manaaki Whenua
Landcare Research

# Potential development of a verified type locality database of species to support the protection of indigenous biodiversity by local government authorities

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# Potential development of a verified type locality database of species to support the protection of indigenous biodiversity by local government authorities

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# Summary

### Project and client

- Otago Regional Council and Environment Canterbury contracted Manaaki Whenua – Landcare Research (MWLR) to provide advice on the potential development of a verified type locality database of plant and other species to support the protection of indigenous biodiversity by local government authorities.

### Objectives

- Provide advice on what kind of type locality data should be prioritised and why it should be prioritised.
- Develop a catalogue of type localities for New Zealand fern species as an exemplar data set. This includes evaluating the quantity and quality of existing data, any data gaps, the work required to fill the gaps, and resulting issues. This will facilitate the extrapolation of the work necessary to develop a catalogue for all organisms.
- Estimate the requirements for scaling up this exercise to cover all New Zealand species.

### Methods

- Type locality data available from MWLR databases, the Global Biodiversity Information Facility (GBIF), and the published literature were extracted and collated.
- Exemplar type locality data were digitised, including geo-referencing and capturing estimated uncertainty.
- Technical information on the different kinds of type was collated and presented.

### Results

- Extant fern data were found to be extensive due to a recent revision. The exercise did allow scaling estimates and the identification of important issues.
- We estimate that New Zealand has between 30,000 and 40,000 species described from New Zealand, most with potential type localities.
- Data providers to the GBIF already mobilise perhaps 50% of the relevant data, but the quality is variable and data on geo-location uncertainty mostly absent.

### Conclusions

- A scaled-up exercise to cover all organism groups is likely to be prohibitively expensive, and we recommend a focus on high-value taxa, such as species listed under the New Zealand Threat Classification (NZTCS) in all categories except ‘Not Threatened’.
- The key priorities for digitisation are: (1) type localities for terrestrial species described after 1940, for which associated locality data are often adequate; (2) a focus on the subset of primary types (holotype, lectotype, neotype or epitype), but excluding

syntypes and paratypes. The one-to-one relationship between a primary type and the species name gives these types (and associated localities) significant value.

- Type locality data have value for taxonomic research on how species are defined and improve our knowledge of species distributions.

**Recommendations**

- Cataloguing projects focused on selected high-value taxa are achievable.
- We recommend a prioritised focus on a subset of type localities associated with what we will define as primary types.
- The subset of more useful post-1940 records should be prioritised for the capture of data on primary types, covering about 20,000 species.
- Existing specimen digitisation initiatives associated with national collections should be given more support.
- Information infrastructure initiatives such as the GBIF and New Zealand Organisms Register play a critical role in supporting biodiversity management, including type localities.

# 1 Introduction

Councils are required to protect areas with significant native biodiversity. The National Policy Statement for Indigenous Biodiversity (NPSIB) established definitions for significant natural areas (SNAs), which are important areas containing native biodiversity. One attribute for the designation of an SNA is the presence of the 'type locality' of an indigenous species. In this report we describe the definition of type localities and present an analysis of how this information could be collated and used. We include estimates for the work required to complete an inventory of New Zealand type localities and suggestions for prioritisation.

# 2 Background to the project

When a new species is first formally described in the scientific literature it is necessary to designate a single specimen as the 'name bearing type' (see later for definitions). A type specimen fixes the application of the scientific name, and type specimens therefore have a critical role in taxonomic research. Type specimens underpin decisions on the designation of new species resulting from the splitting of existing species concepts and the amalgamation of different names as synonyms of a single species. In turn these decisions have consequences for assessing species distributions and associated rarity and threats. Type specimens are therefore treated as the 'crown jewels' in many herbaria, fungaria, and museums and they are included in the Antiquities act 1975 as 'protected New Zealand objects'.[1]

Type localities are important in taxonomic research in addition to their role in stabilising the application of names. A significant number of species in many groups (but especially speciose groups such as insects and fungi) are known only from the type specimens, and some of those specimens may be very old, lost, damaged, or unsuitable for modern molecular-based studies. Knowledge of the type locality enables a focused search for these 'orphaned' species, allowing them to be resolved in a modern sense.

The localities associated with type specimens also have significant value beyond their application to taxonomy. The population in the type locality was representative of the species at the time of description and may provide future information on species definition, genetics, and other organism properties. Many type localities will have undergone significant change over time and the indigenous biota may no longer be present. Certainly for some groups, historical collecting of specimens was focused on easily accessible areas close to habitation, and many of these localities will have been subsequently modified significantly. If a species is still present at a locality, then it may also represent one of the few known locations. Many species in New Zealand have not been fully assessed for their risk of extinction. Many species are uncommon and their distribution poorly documented, and their status remains data deficient under the New

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[1] https://www.legislation.govt.nz/act/public/1975/0041/latest/DLM432116.html

Zealand Threat Classification System (NZTCS[2]). The known locations of data deficient species are important for future assessments.

Manaaki Whenua – Landcare Research (MWLR) maintains three Nationally Significant Databases and Collections (NSDCs[3]), covering terrestrial plants (Allan Herbarium), arthropods (New Zealand Arthropod Collection), and fungi (PDD Fungarium). These are the largest biological collections in New Zealand and they contain many type specimens. The staff associated with the collections comprise the taxonomic experts who carry out research to identify, describe, and classify species, together with the technical support staff who manage the physical and digital collections. The collections and associated staff are supported through the MBIE Strategic Science Investment fund (SSIF[4]). MWLR researchers are well placed to examine the issues relating to the collation of information on type localities, and to provide actionable advice.

Currently there is no verified list of type localities for New Zealand indigenous species. The necessary information is mostly still in non-digital form, and the digital data that are available are scattered, incomplete, and often incorrect.

# 3 Objectives

In this report we explore several issues affecting the use of type localities to designate SNAs.

- What are types and type localities?
- What information on type localities is available in digital form (and what proportion remains undigitised)?
- What issues are associated with the existing data?
- What non-digital gaps are there?
- Where could gap data be sourced?
- What kinds of type localities should be included and prioritised?
- What work is necessary to develop a complete national type locality inventory?

# 4 Methods

Initially we examined in detail what is meant by the term ‘type’ and the implications for prioritising the data collation and digitisation effort.

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[2] https://nztcs.org.nz/

[3] MBIE designated Nationally Significant Databases and Collections: https://www.mbie.govt.nz/science-and-technology/science-and-innovation/funding-information-and-opportunities/investment-funds/strategic-science-investment-fund/funded-infrastructure/nationally-significant-collections-and-databases/

[4] Strategic Science Investment Fund | Ministry of Business, Innovation & Employment (mbie.govt.nz)

To address the remaining objectives, three streams of work were undertaken. In the first workstream we considered the type localities for all New Zealand fern species. The group is relatively small and allowed us to develop a complete type locality inventory, and in the process of assembling this inventory we were able to assess various issues that would affect the development of a broader inventory. Most importantly, this exercise allowed us to assess how long, on average, it takes to address these issues and what resources are needed. The results from this stream of work were used to extrapolate the effort that would be required to develop a complete type locality catalogue for all organisms with New Zealand types.

In the second workstream we examined the available digital data on type specimens across all organism groups. In this exercise we were able to assess the quality and completeness of the existing data and gain insights into potential strategies for prioritising the digitisation work, verifying data, and making estimates of spatial uncertainty.

In the third workstream we combined existing data on known type localities with other data sets to develop estimates of the total number of expected type localities. In addition, this exercise allowed us to derive statistics on the potential regional distribution of type localities, the land use associated with known localities (which may originally have been indigenous habitat but are now modified), and other key attributes of type localities.

# 5 Background to type localities

## 5.1 What are types and type localities?

### 5.1.1 The codes of nomenclature and type collections

The currently accepted scientific naming of organisms dates back to the work of Carl Linnaeus in the 1750s. Codes of nomenclature formalising how these names should be constructed and published were developed much later, in the 20th century, and are retroactively applied to older names. The requirement to designate a type specimen to anchor the application of a name was only included in the nomenclatural codes well after they were established.

The scientific naming of organisms is governed by several different codes of nomenclature. For algae, fungi, and plants (and some protozoans) it is the International Code of Nomenclature for algae, fungi, and plants (ICN). For animals it is the International Code of Zoological Nomenclature (ICZN). For bacteria and archaea it is the International Code of Nomenclature of Prokaryotes (ICNP). When a new name is introduced, the modern versions of these codes generally require the author to designate a single type specimen to anchor the application of that name.

The taxonomy and nomenclature of organisms are intertwined but distinct activities. Taxonomy is the process of classifying organisms into species, genera, families, etc. The characters selected to define a species and how it differs from another species are taxonomic opinions (concepts) based on the available evidence at the time and according to the authors. The taxonomic evidence base, and the associated taxonomic opinions, often change over time. On the other hand, nomenclature deals with the formulation of names that should be applied to the resulting taxon concepts. It is the legalistic objective framework divorced from individual opinion, and the designation of 'types' is part of that nomenclatural framework. The following discussion is restricted to organisms covered by ICN and ICZN (i.e. plants, animals, and fungi).

The use of a type specimen to stabilise the use of names is relatively recent in the history of botanical and zoological nomenclature. Under ICN, before 1958 it was not necessary to designate a type when describing a new species, and it is only since 1990 that the text must specifically state that a particular specimen is the holotype, together with the institution where the type is deposited. Recognised institutions under ICN are those registered with Index Herbariorum.[5]

Under ICN, a name is *validly published* if it passes all the nomenclatural rules for the formulation of a new name. Despite being validly published, a name can still fail to be accepted for other reasons; for example, if the same name has been published before. Under these circumstances the name is said to be *illegitimate* and is not available for use. 'Type' specimens associated with invalidly published names have no formal status while the name remains illegitimate. It is, however, possible to legitimise such a name, at which point the type specimens can be formally recognised.

A similar situation exists under ICZN, but the terminology differs. Under ICZN a name that passes the essential rules for publication is *available* rather than validly published. Similarly, if the name is available but there is conflict with an earlier name, then it is considered *invalid* rather than illegitimate. The different meaning of the same words under ICN and ICZN is unfortunate and potentially confusing.

Any names that do not fulfil the requirements of the code with respect to type designation are incorrectly published and the specimen has no formal status as a type, even though specimen labels may indicate 'type'. These records need to be identified and excluded from any assessment of type localities.

### 5.1.2 Why are there multiple types of type?

The term 'type' is used quite broadly in the non-technical biological literature. The use is often an implicit reference to the holotype specimen, but there are several types of type and some definitions of terms used by taxonomists are appropriate. The following definitions are largely based on the vocabulary applying to names formulated under ICN. The other codes may have additional terms, or different terminology for the same concepts.

The term *protologue* means everything associated with a name when it was first published (e.g. description, diagnosis, illustrations, references, synonymy, geographical data, citation

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[5] Index Herbariorum: https://sweetgum.nybg.org/science/ih/

of specimens, discussion, and comments). The type status of a specimen forms a critical component of the protologue.

The *typification statement* within the protologue will indicate which collections are types, when, where and by whom they were collected, and where they are preserved.

The *typified name* is the originally published name anchored to the type (specimen) for that name. The preferred/accepted name for a species (and its associated collections) may change over time, but the status of a specimen as a type remains fixed and applies only to the typified name.

A *holotype* is the one specimen or illustration either explicitly indicated by the author as the nomenclatural type or used by the author of a taxon when no type was indicated. As long as it exists it fixes the application of the name concerned. The designation of a specimen as the holotype can only occur, explicitly or implicitly, in the protologue and cannot be subsequently designated. The holotype specimen is often referred to as the *name-bearing type.*

An *isotype* is any duplicate of the holotype and is always a specimen.

A *syntype* is also always a specimen. It refers to any specimen cited in the protologue when there is no stated single holotype (usually older published protologues). If the protologue does not explicitly refer to any type collections, then all specimens from a single gathering of the taxon at a particular time and location are syntypes. In the older literature the equivalent term *cotype* may be encountered.

An *isosyntype* is a duplicate of a syntype.

A *paratype* is any specimen cited in the protologue that is neither the holotype nor an isotype. The list of paratypes may be numerous where many specimens were examined and cited as part of the species description. Paratypes are of secondary significance because they are not nomenclaturally bound to typified names. In the original description this material is cited to provide taxonomic information on intra-species variation and distribution, according to the author's taxon concept.

A *lectotype* is a specimen or illustration subsequently selected from the original material as the nomenclatural type if the name was published without specifying a holotype, or if the holotype is lost or destroyed, or if a type is found to belong to more than one taxon. If the original publication mentioned several specimens without explicitly designating a type (before 1958 under ICN), then by definition these were originally syntypes, and one may be selected as the lectotype. Under ICN if the lectotype is lost or destroyed, then the remaining syntypes are available for specifying a replacement lectotype. This marks a difference between ICN and ICZN where the designation of a lectotype means the remaining syntypes are designated as *paralectotypes* and can serve no future role in typification.

An *isolectotype* is a duplicate of a lectotype specimen.

A *neotype* is a specimen or illustration selected to serve as a nomenclatural type if no original material is extant, or if it is missing. To be more specific, if the original description contained no mentioned specimens or illustrations and there is no other original material (as defined above), then it is necessary to designate a neotype because the designation of a lectotype is not possible.

An *isoneotype* is a duplicate of the neotype.

An *epitype* (available since 1994 under ICN) is a specimen or illustration selected to serve as an interpretative type when the holotype, lectotype, or previously designated neotype, or all original material associated with a validly published name, are demonstrably ambiguous and cannot be critically identified for purposes of precisely applying the name to a taxon. The reality is that many older names associated with old type collections will be ambiguous because the descriptions will be limited, and for any material it will be difficult or impossible to extract adequate morphological details or sequence data. Consequently, epitypification has become a popular way to stabilise the application of older names against modern sequenced material, especially for fungi.

An *isoepitype* is a duplicate of the epitype.

Because there was no requirement to specify a type specimen before 1958 under ICN, it is often necessary for modern workers to newly designate a type to fix the application of an older name. Many of the different kinds of type status defined above are related to this retroactive typification process.

These different kinds of types, their precise meaning, and their original or subsequent designation can lead to considerable complexity in the associated data, which has consequences for determining type localities.

### 5.1.3 Typified names, and multiple types per species name

It is critically important to note that the status of a specimen as a holotype is permanently bound to the name for which it is a designated type (typified name). Other kinds of types are bound to varying degrees, through to paratypes, which are not nomenclaturally bound.

A particular taxon concept may incorporate several synonymous names, one of which will have priority (under a code) and should be used as the preferred/accepted name for the species. Consequently, a single preferred name for a species may be associated with multiple types (and typified names and type localities) for each of the synonymous names. Any data resource that includes type localities should also link that type locality to the original typified name and type status. Failure to track this linkage back to the original data may result in false assumptions.

For example, even for permanently bound holotype names, the number of type localities associated with a taxon may change. Consider a species concept that is considered (currently) to have the following fictional set of synonymous names: name A, name B, name C, and name D. In this example, names A-D were considered to refer to distinct, separate species when they were originally described, but subsequent taxonomists have decided they represent the same species (i.e. the species have been ‘lumped’). From the set of four synonymous names in this example, name A has nomenclatural priority (if published first) and should be used to refer to the species concept. Thus, the taxon concept referred to by name A will be associated with different types (and typified names, and type localities) for name A, name B, name C, and name D.

However, it is also quite common for taxonomists to split existing taxon concepts. In this example they may decide that name A and name B represent one species and name C and name D represent a different species. The code requires that the first species be called name A (it still has priority over the synonymous name B). Consequently, the taxon concept associated with name A has changed even though the name remains the same. The name for the second species will depend on nomenclatural priority between name C and name D. The consequence of this splitting is that the four type localities linked to name A have become two localities linked to the new concept of name A and two linked to the concept that includes name C and name D.

The names linked to species concepts (and the number of associated types) are dynamic and can change over time. If the only link between a type locality is to the first concept of name1, then it is not possible to infer the necessary splitting of the four original linked type localities after the taxon split, and the type locality data can no longer be interpreted correctly. Consequently, if a specimen has the status of a ‘type’, then it is critically important to know the typified name and not just the currently accepted name for the associated species.

For paratypes the situation can be much more complex. This issue of a potential disconnect between type status, typified name, and the current identification or accepted name is of particular concern for data sourced from the GBIF[6], as we will see later.

### 5.1.4 Primary types as a priority for digitising type localities

The principal type localities are those for a holotype, lectotype, neotype or epitype, and of these the holotype locality should be the focus of digitisation and collation efforts. The localities associated with all these types are more significant than the localities of paratypes, or even syntypes. For this reason, in this report we will refer to these as *primary types*. They represent the set of a unique type specimen associated with a particular name.

From a nomenclatural perspective paratypes have limited significance to a typified name. They are also not guaranteed to represent the same species as the holotype. Subsequent workers will often examine paratypes and consider some to be misidentified, or some may form part of a separate species concept when taxa are split. Paratypes, being only loosely bound to the name for which they were established, are especially prone to the issues discussed in the previous section and of much lower relative significance than primary types. For these reasons the information on paratype status is often not captured in collection management systems or digitisation efforts. Similarly, syntypes are an indication that a name was published before the recognition of (holo)type status. There

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[6] https://www.gbif.org/

may be many syntypes for each species name, and because they are associated with old publications, the associated type localities are often omitted or too vague to be of use.

The one-to-one relationship between a primary type and the species name gives these types (and associated localities) significant value for taxonomic research. From a biodiversity management perspective they may have enhanced value when they refer to species in any category in the NZTCS except 'Not Threatened'.

## 5.2 Sources of information on type localities

There are two principal sources of information on type localities. Type specimens are designated as such (either explicitly, or implicitly for old names) in the original publications describing the species. Type localities form part of the typification statement in the protologue. For the name to be officially published and recognised, the data in those publications must adhere to the requirements of the relevant code of nomenclature. If the name is not published correctly, then any associated data on 'types' can be dismissed. Consequently, it is important to know if a potential type specimen is associated with a correctly published typified name.

The basic requirement for establishing a type specimen in the protologue is to enable that specimen to be located by subsequent researchers (e.g. details on the institution holding the specimen, and perhaps the accession number). The related data on where the specimen originally came from is not governed by the nomenclatural codes, and the presence and precision of that type locality data in the typification statement is variable. Quality and completeness of type locality data are especially problematic for older names. Consequently, the original publication may or may not be correctly published, may or may not explicitly designate a type specimen, and the associated data may or may not include adequate information on the type locality.

For most organism groups in New Zealand the online information on names and associated published typification data are variable in availability and quality. Some groups are associated with regularly maintained, internet-accessible, published national checklists, sometimes with synonyms but rarely with typification information. Mostly these data are not collated, not available online or digitised, or not current.

MWLR maintains the national databases of organism names for plants and fungi. These databases provide an example of national-scale species name information that is digitised and continuously managed. These 'names databases' track the relationships between names and provide the currently accepted name for a taxon and the associated set of synonymic names. These names databases also track the published literature relating to the names, including the original publications in which names are first described. Sometimes the digitised name data in these databases include a copy of the typification statement from the original publication. This provides a useful source of information for types not held by MWLR, but the typification data for New Zealand names are incomplete.

The combined name-based data are available through the BIOTA of New Zealand website (BIOTANZ).[7]

A second important source of information on type localities is associated with the type specimen and any associated notes. The details of specimen data may not be digitally available, and sometimes even the whereabouts of the type specimen is uncertain. That uncertainty may include limited knowledge on which institutional collection around the world holds a particular specimen – if it exists at all – and where within a collection the specimen is located. Many collections do not hold complete digital catalogues of the material they house, including the Royal Botanic Gardens at Kew and the Natural History Museum in London, where many New Zealand specimens from the early colonial era are stored. Material may have been lost or destroyed in the past. Often it is necessary to visit potential collections and physically search for the specimens.

Despite these shortcomings, in recent years there has been significant progress in digitising and making available digital information associated with specimens, including type specimens (which are often a priority for digitising). Much of this information is aggregated and made available in a shared format through the GBIF, an inter-governmental organisation with 45 voting countries currently contributing to its support, including New Zealand.

For this project all GBIF data for New Zealand associated with type specimens were downloaded[8] on 1 August 2024. The details of query used to extract the data, and the necessary citations for use of the data, are provided in the Appendix.

# 6 Methods

## 6.1 Workstream 1: a catalogue of New Zealand fern type localities

The purpose of this exercise was to develop a type locality catalogue for New Zealand ferns as a small-scale study allowing us to estimate the effort and complexity required for an extrapolation to all organism groups.

We assembled a preliminary data set of existing information on type localities of New Zealand fern species. This data set contains a combination of the type data for specimens held in CHR, the typification statements captured in the MWLR names database, and the data on fern-type specimens mobilised through the GBIF.

The intention was for this data set to demonstrate incomplete information on types, type localities, associated geo-references, and uncertainty/bounds associated with geo-references. In fact the resulting data set contained more information than is typical for

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[7] BIOTA of New Zealand https://biotanz.landcareresearch.co.nz/

[8] GBIF.org (1 August 2024) GBIF Occurrence Download https://doi.org/10.15468/dl.7dynh3

most groups because of a recent revision of the taxonomy of New Zealand ferns.[9] For this reason, we added the taxonomic group of fern allies to the preliminary data set. The data set was compiled into a spreadsheet and used as the basis for adding missing information, assessing the accuracy of existing data, and adding information on the uncertainty of type localities. Most importantly, the time required to address each aspect of the process was tracked, allowing us to estimate the time and resources required for a complete type locality inventory. Addressing these issues specifically for species of ferns and fern allies highlighted the following broader issues.

### 6.1.1 Locating and viewing the original publications

Literature references for the original publication of a scientific name are usually relatively straightforward to trace. The MWLR names databases provide citations for the names of organisms associated with our collections. More broadly, the New Zealand Organisms Register (NZOR[10]) also provides some name publication details, although it is often incomplete for many groups.

At the global scale there are nomenclatural databases (nomenclators) that capture publication details. For plants it is the International Plant Names Index (IPNI);[11] for fungi it is IndexFungorum[12] (IF); and for many animal names it is ZooBank.[13] However, having a literature reference does not necessarily mean it is straightforward to locate and view the original publications. Many citations, especially to early names, are found to contain errors.

Accessing the content of these publications (those that are correctly cited) is dependent on the obscurity and date of the publication. Many of the more obscure New Zealand publications will be held in institutional libraries, although increasingly these libraries, and their associated staff, have been reduced and the remaining material moved to off-site archival centres and so are not easily accessible. The National Library of New Zealand provides digital access to many of the early local publications. Many well-known and/or rare old books and journals are out of copyright (95 years before present) and the scanned digital content is available through the Biodiversity Heritage Library (BHL[14]) website. The BHL also contains more recent material that has been made available free of copyright restrictions.

BHL content has been specifically indexed for organism names, which makes searching for publications straightforward. Plazi[15] is a platform providing access to digitised taxonomic treatments extracted from a broad range of literature. It operates on the premise that taxonomic descriptions are facts and not subject to copyright, although the broader article

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[9] https://www.nzflora.info/publications.html#ferns-lycophytes

[10] https://www.nzor.org.nz/

[11] https://www.ipni.org/

[12] https://www.indexfungorum.org/

[13] https://zoobank.org/

[14] https://www.biodiversitylibrary.org/

[15] https://plazi.org/

from which these facts were derived may have copyright restrictions. For many New Zealand invertebrates the BUGZ[16] database provides access to publications, and like BHL content it is specifically indexed for organism names.

An increasing number of recent publications are in open-access journals, but a substantial number are behind paywalls. Crown Research Institutes, universities and other academic institutions usually have subscription access to a broad array of publications, but local authorities generally do not have subscription access to scientific literature. Non-institutional access to original publications through the inter-library photocopy services costs, on average $15 per article. The loan of physical books, especially from overseas, can be considerably more expensive. Non-institutional purchase of papers from the publishers can vary significantly in cost but is generally around $100 per item.

### 6.1.2 Locating and verifying the status of type collections

Many New Zealand type specimens reside overseas in major collections such as the Natural History Museum in London. Many institutes around the world are in the process of (or have completed) digitising the data associated with their collections; MWLR and other institutes within New Zealand have partially digitised their collection data. Many institutes also provide a regular copy of the available digital data to the GBIF, where it is aggregated and made available via the GBIF portal.

To share data through the GBIF, each data provider must convert their data into an agreed standard format. Species occurrence data conforms to the Darwin Core[17] standard, which provides data fields for specifying the type status of a collection and the typified name. Often, however, the typified name is not stated explicitly and the type status is therefore ambiguous.

In addition, the designation of a specimen as a type does not necessarily ensure that it does have an officially recognised type status. Sometimes the depositor of a specimen will annotate it as a type with the future intention of designating it, but without subsequently publishing it. Sometimes the type status is linked to a typified name that is incorrectly published, and so the type has no formal status. Sometimes the status of a specimen is annotated as a type but without specifying what kind of type, thus obscuring whether the specimen is a primary type. And sometimes there are straightforward errors in the annotations as a type.

In New Zealand, GBIF data providers include MWLR, Museum of New Zealand Te Papa Tongarewa (WELT), NIWA, and Auckland Museum (AK). Most other New Zealand institutional collections are not currently available via the GBIF (e.g. Otago University herbarium [OTA]). Some of these regional collections provide online information on types, but knowledge of their existence, coverage, and format is variable.

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[16] https://bugz.ento.org.nz/

[17] https://dwc.tdwg.org/

### 6.1.3 Geo-referencing type localities and associated uncertainty

There is a recommended GBIF best-practice document[18] for capturing specimen geo-location data from historical records, and some providers of data to the GBIF will adhere to these recommendations.

Species names published in the 18th and 19th centuries are often associated with poor type locality data, either as part of the publication of the name or associated with the original specimens. In this period many species were described by workers in Europe based on collections returned from early voyages or sent to them by resident colonists. It was not necessary to designate a single type specimen at that time, and often localities are described by collectors in very general terms, usually just 'New Zealand'. Often the current location of any specimens is uncertain, and material has been lost or destroyed. Even when a more precise locality was specified, the subsequent knowledge of that locality may have been lost, is ambiguous, or has changed in extent significantly. Consequently, from a prioritisation perspective it is important to know when a species was described, and this aspect of available data will be covered later.

For more recent collections the associated locality information will generally be more precise. However, it has not been general practice to record geographical coordinates until relatively recently, and then based on paper maps, and often approximated to 10 km grid squares. It is only in the last two decades that more precise GPS-derived point latitude/longitude coordinates and associated uncertainty have been available, and even then the collectors frequently do not specify the geodetic datum for the GPS coordinates.

The bulk of geo-referenced localities available for historical collections are inferred from geo-coding the locality place names within publications or from specimen annotations. For some older, historically digitised data the inferred geo-coordinates were derived from early versions of the New Zealand Gazetteer[19] matched against some recognisable component of the locality string. These early versions of the New Zealand Gazetteer associated a place name with the position of Topo-map labels, thus introducing variable uncertainty. The current version of the gazetteer is more precise. This problem also affects older attempts to infer locations based on place name labelling on paper maps. There are many tools available for automated geo-coding based on simple place names and/or addresses.

Locality strings captured as specimen annotations can often be quite specific. For example, the typification statement for *Chaeteosphaeria bombycina* T.J.Atkinson, A.N.Mill. & Huhndorf includes '*HOLOTYPE: NEW ZEALAND: North Island, Ohakune, Jubilee Park, around 100 m along the track that enters the park from Burns St.*'. With some effort this string can be transformed into an accurate geo-location much more accurately than

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[18] A Chapman, J Wieczorek 2020. Georeferencing best practices. https://doi.org/10.15468/doc-gg7h-s853

[19] https://gazetteer.linz.govt.nz/

simple place name geo-coding. There are tools to support the automated geo-referencing of these descriptive locality strings, such as GeoLocate.[20]

Within MWLR the current practice for inferring localities associated with older specimens has been to construct a database of standard localities. This is a subset of place name strings that have been verified and can be applied to multiple specimen records, thus reducing the digitisation effort. These standard localities often reflect the significant effort that has gone into tracing the particular use of a locality name when there may be some ambiguity, such as place name homonyms. These standard localities may also be associated with inferred values for uncertainty. This uncertainty can take the form of a radius of uncertainty around a point, or a polygon in the form of a WKT[21] string. The advantage of the latter is the increase in precision that can often be inferred, perhaps based on habitat; for example, littoral or riparian species, where a bounded linear geometry can be much more precise than a point/radius value. Once again, there are online tools promoted by the GBIF that can help capture these point/radius and WKT measures of uncertainty, such as GeoPick[22].

For any mass digitisation project of type localities there would be significant gains in efficiency through the provision of a customised geo-referencing web portal. This could include available national and regional, current and historical maps and aerial/satellite imagery, gazetteers, and available standard localities. Some of the relevant GIS layers are available at the regional scale (e.g. Canterbury Maps[23]), but there is no national-scale single resource, and none with additional digitisation tools to display user point data, including the ability to capture point/radius and/or polygon WKT data, which would be ideal.

The geo-location data, and uncertainty estimates for the collated data on fern and fern allies where type specimens are held by CHR, were generally captured using the approach of using standard localities and an associated 4-polygon describing uncertainty. For GBIF-sourced data, each locality was treated individually and the points assessed using available mapping resources.

## 6.2 Workstream 2: analysis of available digital data on New Zealand types

Specimen data associated with New Zealand primary types and currently mobilised by the GBIF were extracted and downloaded. The process and the data set are described in detail in the Appendix.

The GBIF data, in DarwinCore format, contain information on the identification of a specimen, its type status (often in rather variable and non-standardised form), along with

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[20] https://www.geo-locate.org/

[21] https://en.wikipedia.org/wiki/Well-known_text_representation_of_geometry

[22] https://biss.pensoft.net/article/111036/

[23] https://canterburymaps.govt.nz/

variable data on higher classification, locality names, a geo-reference, and the uncertainty associated with that geo-reference. We carried out a basic analysis of these data.

## 6.3 Workstream 3: combining available data with other data sets

For the analyses presented in this report we needed additional taxon-level data that are not part of the GBIF download. For this project we needed to ascertain:

- the higher classification we use in New Zealand, which may differ from that supplied with GBIF data
- the currently accepted name in New Zealand for the taxon
- where and when the original typified name was published
- the biostatus of the taxon in New Zealand as indigenous/endemic
- the threat classification of the taxon
- the total number of indigenous/endemic species (and associated typified names) used in New Zealand
- the nomenclatural status of names as legitimately published.

### 6.3.1 The use of NZOR in facilitating access to broader taxon data

Access to these additional data is facilitated by NZOR. NZOR, and the associated services, are essential tools for standardising, cross-linking, and enhancing New Zealand biodata.

The first task is to cross-link the names provided in the GBIF download with the standard set of names in the NZOR, and associate name data with NZOR unique identifiers. In addition to providing access to the data provided by the NZOR, these identifiers facilitate the unambiguous linking to other, external, sources of taxon data, and for this project that is the New Zealand Threat Classification (NZTCS[24]) data.

The process of matching a list of user-provided names to NZOR entries is facilitated by the NZOR matching service. The end user provides a set of name strings, and the service returns a set of nearest-matched NZOR names and their NZOR identifiers. This service considers the inevitable variations in spellings that occur when people type scientific names, and resolves issues relating to the inclusion, or omission, of author citations, which are often appended to scientific names. During this project (and several months prior) the NZOR matching service does not deliver any results. The issue has been reported to the NZOR manager.

For this project we needed an alternative solution to the NZOR matching service. The NZOR also provides a service for downloading the data content of taxonomic sectors, and we used this service to download the NZOR data for the kingdoms Animalia, Plantae, Fungi, Chromista, Archaea, Bacteria, and Protista. Having these data allowed a simple string matching between the names in the GBIF data set and the NZOR data. However, we

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[24] https://nztcs.org.nz/

could not easily take into account spelling variations or author strings in this simple matching, and so only a subset of GBIF-sourced names could be linked to NZOR entries.

During this process we encountered additional issues we were unable to resolve. The NZOR sector download is available as either a comma-separated values (CSV) file or a tab-separated values (TSV) file. In both cases the NZOR download file was found to be corrupted by formatting issues, resulting in the loss of some entries. The errors were different in each download, and so we reconstructed the maximum number of valid entries from both CSV and TSV data sets and used the result for simple matching against the GBIF data.

Inspection of the resulting NZOR data set revealed additional issues we were unable to resolve. The NZOR is designed to ingest data from different taxonomic data sources/providers and to automatically merge any overlapping data into a single unified view of species names (and synonyms) used in New Zealand. To achieve this merger the NZOR system carries out an internal matching process between name data from different providers. That process may have a fault, because the downloaded data contains multiple records for the same name. For example, at the time of writing, an NZOR website search for *Dasytricheta waihoana*, *Ablabus discors*, and *Dendrobium cunninghamii* will reveal the multiple versions, and there are very many similar entries.

The NZOR ingests informally published 'tag names' that have not been formally published. These are important because they are often associated with threat assessments, where informal species concepts are often included. In the downloaded NZOR data we found no simple way to differentiate these tag names from formally published names. Formally published names will be associated with valid type localities, but tag names will not. The inability to separate these two kinds of names has an impact on the potential number of typified names in New Zealand.

Finally, we observed that a significant number of names in the GBIF data should be part of the NZOR in some form but do not seem to be present. These residual unmatched names are associated with organism groups where there isn't an adequately maintained, national-scale taxonomic data source currently feeding data into the NZOR. The data suggest this issue primarily affects some animal groups.

### 6.3.2 Use of GBIF geo-location data to combine data sets

In addition to estimating the work required to develop a complete species type locality catalogue, we used the existing GBIF data to explore some of the potential simple uses of such data, based on known type localities. We emphasise that only a fraction of the GBIF data have associated geo-references and can be mapped as point locations, and these locations remain unverified and without associated uncertainty measures. In the analyses, we made no attempt to add additional missing geo-reference data and did not verify any of the existing data. Neither did we use any uncertainty data associated with geo-references.

The analyses provide relative rather than absolute values of the subset of geo-referenced type localities for each regional council. These measures include the partition of existing data by regional council boundary, and the insight provided by intersecting location data with the Land Cover Database (LCDB). These analyses were carried out using the QGIS[25] software, together with the council boundaries from StatsNZ[26] and LCDB5.[27]

# 7 Results

## 7.1 Workstream 1: a catalogue of New Zealand fern type localities

The results of reviewing and extending type locality information for ferns and fern allies can be summarised as follows.

### 7.1.1 Resolving published typification data

- For older typified names, the literature generally provides more locality information than associated specimen label data.
- Early type locality information, where it is mentioned at all, is usually broad (New Zealand) or difficult/impossible to accurately resolve.
- Sixty percent of the associated literature was found in open-access sources.
- Nine percent of the remainder was restricted (paywalled) access.
- Thirty-one percent of articles could not be traced from the available citations for the original publication. This substantial issue is usually an indication of errors in early citations that have been persistently transmitted by subsequent workers. The work required to resolve these issues can be considerable, and often results in poor information on type localities even when the sources are traced.

### 7.1.2 Reviewing extant GBIF type locality data

- For records sourced from herbaria outside New Zealand, any geo-referencing shows evidence of poor quality, with little attempt to resolve potential place name homonyms, or even between different features that may carry the same name (e.g. rivers/lakes, towns, districts).
- Records from New Zealand herbaria (WELT, AK, CHR) demonstrate significantly better geo-referencing, generally within 1 km for many records. This is probably a consequence of these herbaria adopting geo-referencing protocols based on known standard localities.
- Despite increased quality of locally sourced data, 16% of CHR type localities required some amendments to the locality data.
- The geo-location records of some threatened species indicate that precise locality data have been obscured or dithered, but without annotation to indicate that data have been supressed or altered.

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[25] https://www.qgis.org/

[26] https://datafinder.stats.govt.nz/layer/111182-regional-council-2023-generalised/

[27] https://lris.scinfo.org.nz/layer/104400-lcdb-v50-land-cover-database-version-50-mainland-new-zealand/

- Historically geo-referenced localities show evidence of shifts due to different interpretations of locality based on the different names and locations of labels used on different map series over time.
- Data for type localities since 1980 show a significant increase in presence and accuracy.

## 7.2 Workstream 2: analysis of available digital data on New Zealand types

Our analysis concerns primary types, so it specifically excludes paratypes. We do not consider paratypes to have significant value in relation to potential SNA designation. The initial download of GBIF data used for this analysis excluded non-primary types, except syntypes.

The GBIF download of New Zealand primary type data (see Appendix) included data from 427 data sets from 23 countries. There are 32,903 New Zealand occurrence records flagged with some kind of type status. The supplied type status data are variable in format and we have simplified them into standard categories (Table 1): 5,961 records are flagged simply as 'Type' without specifying the kind of type. In this analysis we have assumed the majority of these will be primary types. In total there 28,406 primary type records.

**Table 1. GBIF type occurrence data**

| Type category | No. of GBIF records | Primary type |
|---|---|---|
| Epitype | 27 | Yes |
| Hapantotype* | 4 | Yes |
| Holotype | 21,398 | Yes |
| Isotype | 4,215 | Yes |
| Lectotype | 2,620 | Yes |
| Neotype | 142 | yes |
| Not a type | 28 | No |
| Paralectotype | 6 | No |
| Syntype | 4,463 | No |
| **Total** | **32,903** | |

* A protistan type consisting of multiple cells in a preparation (e.g. a slide).

Within the set of primary type records none have the recommended form, including a concatenated typified name, although it is probable that the GBIF has parsed the supplied typified name data prior to publication on the GBIF website. Just 15% of records have a separate, explicitly designated typified name. Consequently, for the bulk of the data we have no guarantee that the name supplied with a record (the identification name) is the typified name to which the type status is applied. The omission of the typified name (in a simple format) is a significant omission and reduces the value of the data considerably. In this exercise we have assumed that the name supplied with a record is the typified name, unless it is explicitly stated.

The subset of 28,406 records of primary types is associated with 13,968 unique names. The presence of multiple records per name is primarily a consequence of many isotype records, together with a duplication of data associated with both type specimens and the corresponding typification data from the published literature. The latter duplication is distinguished in the GBIF data set by the basisiOfRecord field. For specimen-based data this field contains the text 'preserved specimen' rather than 'material citation', 'occurrence' or 'human observation'. The appearance of duplicates has limited significance because each unique, typified name will be associated with the same type locality data. It is the number of unique names that provides the basis for the estimate of types digitised.

### 7.2.1 Breakdown of GBIF type data by organismal group

The breakdown of primary type data by kingdom and phylum is shown in Table 2. In this table the higher classification for kingdom/phylum is that provided by the GBIF. As mentioned above, these data will contain multiple type records for the same species. We provide both the number of records and the associated number of unique names.

In considering the application of type locality data to SNA designation, and the priorities for digitisation effort, it is worth considering several factors.

- Type locality data for highly mobile animals have reduced value, unless there is some strict association with a localised habitat at that locality.
- In many groups, and especially the Animalia, diversity is dominated by marine groups and so is not relevant to terrestrial SNA designation.
- Figures on available digital data for Animalia are the highest, but are still relatively lower than might be expected given the number of described species, and this may reflect the restricted degree to which data on animal types have been digitised, and subsequently made available to the GBIF.

**Table 2. Primary type data, by taxonomic group**

| Kingdom | Phylum | No. of records | No. of names |
|---|---|---|---|
| Animalia | Not specified | 24 | 8 |
| Animalia | Acanthocephala | 2 | 1 |
| Animalia | Annelida | 338 | 192 |
| Animalia | Arthropoda | 8,605 | 5,870 |
| Animalia | Brachiopoda | 36 | 14 |
| Animalia | Bryozoa | 635 | 334 |
| Animalia | Chordata | 655 | 397 |
| Animalia | Cnidaria | 554 | 238 |
| Animalia | Ctenophora | 1 | 1 |
| Animalia | Dicyemida | 33 | 5 |
| Animalia | Echinodermata | 328 | 181 |
| Animalia | Gnathostomulida | 2 | 2 |

| Kingdom | Phylum | No. of records | No. of names |
|---|---|---|---|
| Animalia | Hemichordata | 9 | 2 |
| Animalia | Kinorhyncha | 22 | 16 |
| Animalia | Mollusca | 984 | 680 |
| Animalia | Nematoda | 338 | 216 |
| Animalia | Nematomorpha | 1 | 1 |
| Animalia | Nemertea | 14 | 8 |
| Animalia | Onychophora | 4 | 3 |
| Animalia | Platyhelminthes | 89 | 78 |
| Animalia | Porifera | 1,396 | 458 |
| Animalia | Sipuncula | 4 | 2 |
| Animalia | Tardigrada | 5 | 3 |
| Animalia | Xenacoelomorpha | 4 | 1 |
| **Animalia total** | | **14,083** | **8,711** |
| Archaea | Methanobacteriota_B | 4 | 4 |
| Archaea | Thermoproteota | 1 | 4 |
| **Archaea total** | | **5** | **5** |
| Bacteria | Acidobacteriota | 1 | 1 |
| Bacteria | Actinobacteriota | 2 | 2 |
| Bacteria | Aquificota | 1 | 1 |
| Bacteria | Armatimonadota | 1 | 1 |
| Bacteria | Bacteroidota | 4 | 4 |
| Bacteria | Campylobacterota | 1 | 1 |
| Bacteria | Chloroflexota | 1 | 1 |
| Bacteria | Cyanobacteria | 6 | 2 |
| Bacteria | Deinococcota | 1 | 2 |
| Bacteria | Desulfobacterota | 2 | 2 |
| Bacteria | Firmicutes | 2 | 2 |
| Bacteria | Firmicutes_A | 14 | 14 |
| Bacteria | Firmicutes_C | 1 | 1 |
| Bacteria | Fusobacteriota | 2 | 2 |
| Bacteria | Proteobacteria | 17 | 17 |
| Bacteria | Thermotogota | 1 | 1 |
| Bacteria | Verrucomicrobiota | 2 | 1 |
| **Bacteria total** | | **59** | **55** |
| Chromista | Ciliophora | 3 | 3 |
| Chromista | Foraminifera | 43 | 34 |
| Chromista | Haptophyta | 7 | 3 |
| Chromista | Myzozoa | 4 | 3 |

| Kingdom | Phylum | No. of records | No. of names |
|---|---|---|---|
| Chromista | Ochrophyta | 602 | 214 |
| Chromista | Oomycota | 14 | 7 |
| **Chromista total** | | **673** | **264** |
| Fungi | Not specified | 14 | |
| Fungi | Ascomycota | 3,065 | 1,429 |
| Fungi | Basidiomycota | 1,796 | 1,180 |
| Fungi | Chytridiomycota | 3 | 3 |
| Fungi | Glomeromycota | 8 | 6 |
| Fungi | Mucoromycota | 10 | 7 |
| **Fungi total** | | **4,896** | **2,625** |
| Plantae | Not specified | 2 | |
| Plantae | Anthocerotophyta | 41 | 10 |
| Plantae | Bryophyta | 2,748 | 409 |
| Plantae | Charophyta | 43 | 9 |
| Plantae | Chlorophyta | 178 | 57 |
| Plantae | Marchantiophyta | 1,680 | 451 |
| Plantae | Rhodophyta | 939 | 216 |
| Plantae | Tracheophyta | 7,337 | 1,985 |
| **Plantae Total** | | **12,968** | **3,137** |
| Protozoa | Not specified | 5 | |
| Protozoa | Amoebozoa | 1 | 1 |
| Protozoa | Choanozoa | 2 | 2 |
| Protozoa | Metamonada | 1 | |
| Protozoa | Mycetozoa | 7 | 4 |
| Protozoa | Sarcomastigophora | 1 | |
| **Protozoa total** | | **17** | **7** |
| **Total for all kingdoms** | | **32,701** | **14,804** |

### 7.2.2 Breakdown of GBIF type data collection year

Figure 1 shows the annual breakdown of number of collections per year for records where the collection year is stated (18,952 records, 67%). Part of the reason for low numbers in the early years is the absence of even basic data, such as the year of collection.

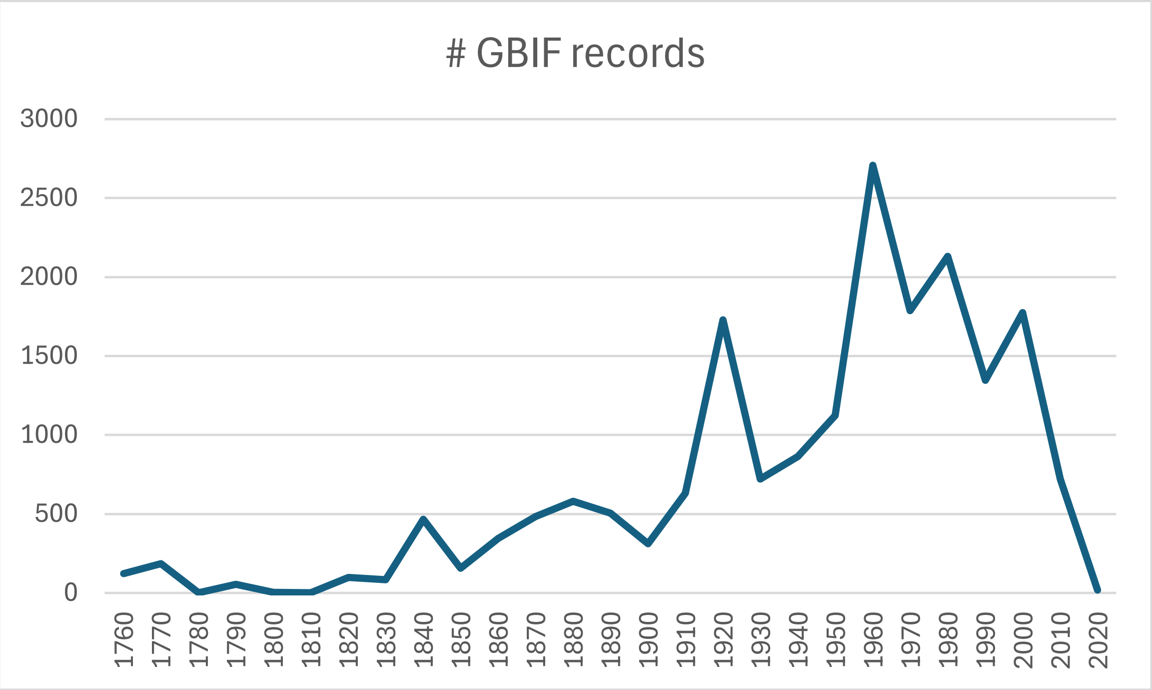

**Figure 1. Primary type collections, by year.**

The peak in the 1920s is due to extensive collections of arthropods by Tonnoir, Edwards and Alexander working on groups such as flies. The subsequent peaks represent many taxonomic groups. It is perhaps interesting to note that the Department of Scientific and Industrial Research[28] (DSIR) was established in 1926 and disestablished in 1992: the number of type collections (and correspondingly the description of new species) in the post-DSIR period has dropped substantially, perhaps associated with a loss of professional taxonomic expertise at that time.

Of the GBIF primary type records with a year (18,952), a subset of 13,416 are associated with a geo-referenced type locality (70% of the total). Later records have a greater degree of geo-reference data. This reflects the fact that modern records generally do have increased geo-reference data provided by the original collector, or that geo-references can be easily inferred from the notes associated with the specimen. However, it also reflects the fact that early type specimens have poorly annotated type locality data that cannot easily be inferred.

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[28] DSIR was the New Zealand Government science research agency before the formation of multiple corporatised Crown Research Institutes.

The figure of 70% of available data with geo-references is probably not far short of the total number of records that could be expected to be associated with a defined, geo-referenced type locality.

From a prioritisation perspective we suggest that 1940 represents a useful breakpoint, when subsequent records begin to be associated with meaningful type locality data. Post-1940 records represent 58% of the total.

### 7.2.3 Geographical distribution of primary type localities

Figure 2 shows the map of all geo-located records of GBIF primary type data, with or without a specified year. This subset contains 17,524 records. Of these, only 2,235 (13%) have an associated degree of uncertainty. The addition of critically important uncertainty data to existing geo-located type-locality records will be a substantial task.

**Figure 2. Geographical distribution of GBIF primary types.**
**Note: shading = density of overlapping records**

Figure 2 demonstrates the occurrence of marine type records, which represent about 10% of the data.

Figure 3 shows the terrestrial distribution of plant records, and the other major taxonomic groups show a very similar pattern. Off-shore points are islands or geo-coding errors. New Zealand plant types represent a relatively well-documented group with available GBIF data.

**Figure 3. Geographical distribution of GBIF terrestrial plant primary type data. Note: shading = density of overlapping records)**

## 7.3 Workstream 3: combining available data with other data sets

Geo-located data from the GBIF were combined with other data sets to provide additional context. These analyses are intended to demonstrate some of the simple and potentially useful information that can be derived from type locality data, including regional priorities. We present a breakdown of the existing data by regional council, associated land use, and threat status. Some limited data are available through the NZOR to consider organisms specifically associated with freshwater environments and their distribution across the regions. That analysis has not been carried out in this project.

### 7.3.1 Distribution of GBIF primary type localities, by regional council

The geo-referenced data on GBIF primary types was intersected with the regional council boundaries to provide the breakdown presented in in Table 3, which shows that 13,984 records lie within regional council boundaries and the remainder offshore or otherwise outside the boundaries.

**Table 3. Regional breakdown of geo-located GBIF primary type records**

| Regional council | All primary types | Animalia | Plantae | Fungi |
|---|---|---|---|---|
| **Area outside** | 577 | 360 | 143 | 22 |
| **Auckland** | 1,483 | 699 | 272 | 489 |
| **Bay of Plenty** | 352 | 228 | 62 | 58 |
| **Canterbury** | 1,601 | 522 | 690 | 377 |
| **Gisborne** | 78 | 38 | 24 | 16 |
| **Hawke's Bay** | 221 | 66 | 67 | 86 |
| **Manawatū-Whanganui** | 702 | 323 | 206 | 169 |
| **Marlborough** | 343 | 144 | 153 | 36 |
| **Nelson** | 332 | 282 | 16 | 26 |
| **Northland** | 1,182 | 539 | 444 | 153 |
| **Otago** | 1,445 | 614 | 515 | 298 |
| **Southland** | 1,309 | 584 | 465 | 207 |
| **Taranaki** | 178 | 54 | 66 | 49 |
| **Tasman** | 876 | 415 | 276 | 180 |
| **Waikato** | 637 | 259 | 183 | 190 |
| **Wellington** | 936 | 378 | 190 | 341 |
| **West Coast** | 1,732 | 655 | 699 | 363 |

The data in Table 3 provide a snapshot of progress with making geo-referenced type data available through the GBIF and the relative number of type localities per region. Although these data are incomplete, they are probably representative of the national and regional relative breakdown.

We stated earlier that GBIF data contain duplications, and so the true number of available type localities will be a subset.

### 7.3.2 Relationship between primary type localities and current land use

We felt it would be instructive, from the perspective of designating SNAs, to consider the current land use (from the Land Cover Database v5.0) associated with existing geo-referenced type localities. We have broken this down by the major organism groups. However, we must stress that only 10% of existing data have a quantified degree of uncertainty associated with geo-coordinates, and many point localities are in error. The uncertainty in many coordinates is likely to encompass multiple LCDB polygons, and so without uncertainty data and verification of point localities this analysis is indicative only.

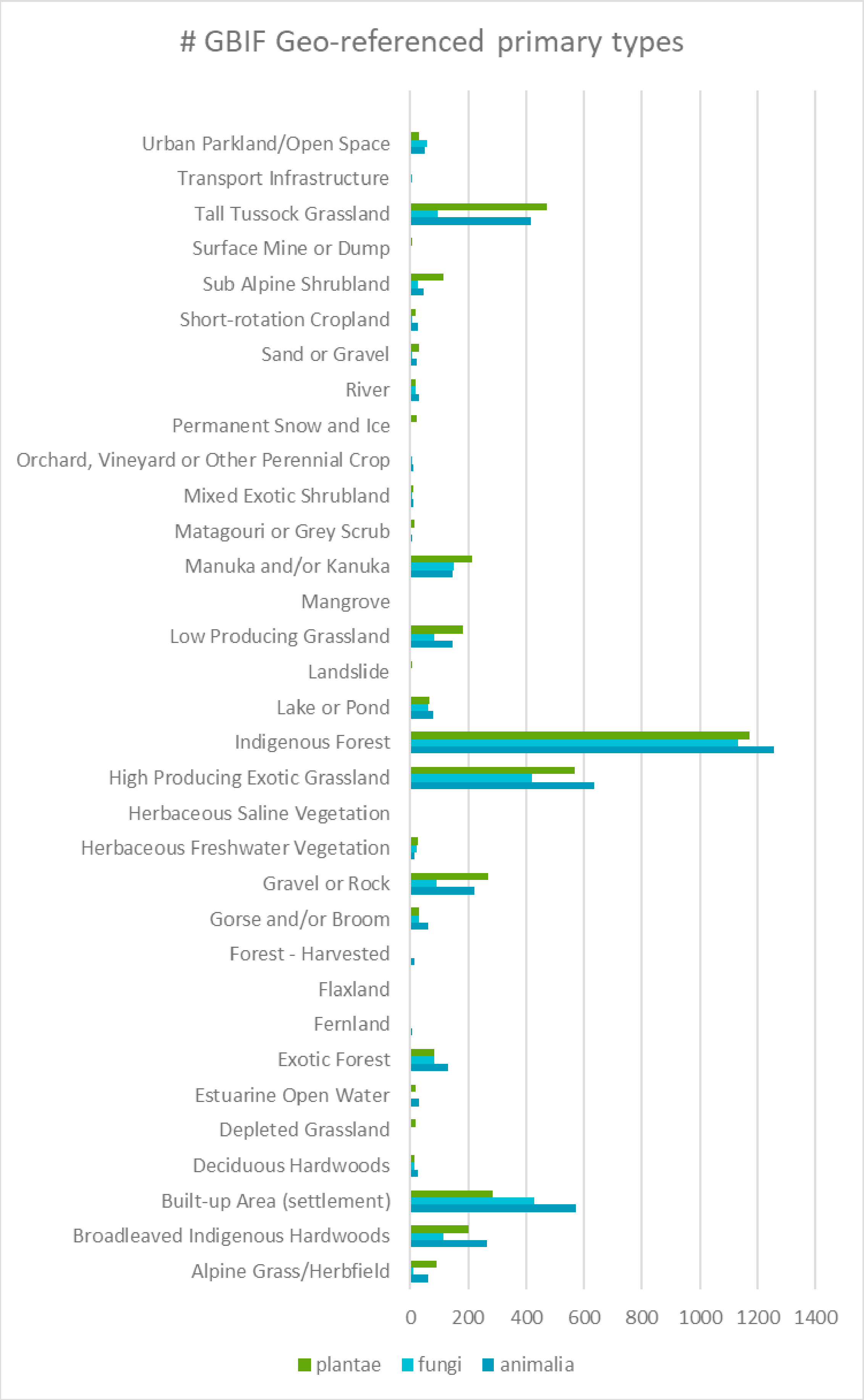

**Figure 4. Breakdown of type localities, by land use.**

In Figure 4 the high figures associated with Indigenous Forest and Tussock Grassland are perhaps to be expected. However, the high figures associated with Built-up Areas and High Producing Exotic Grassland imply that land use may have changed after some of these native organisms were collected and named. These may represent type localities that have already been lost to land-use change. The data provide pointers to similar high-risk localities that have not yet been lost, and this aspect of the data is worth more detailed examination.

Here we provide a further regional breakdown of the type locality data associated with some modified urban/infrastructure areas (LCDB classes 1, 2, 3, and 6), and some modified agricultural areas (LCDB classes 30, 33, 40, 44, 56, 64, 68, and 71); in other words, type localities in some areas most affected by land-use change with respect to indigenous species.

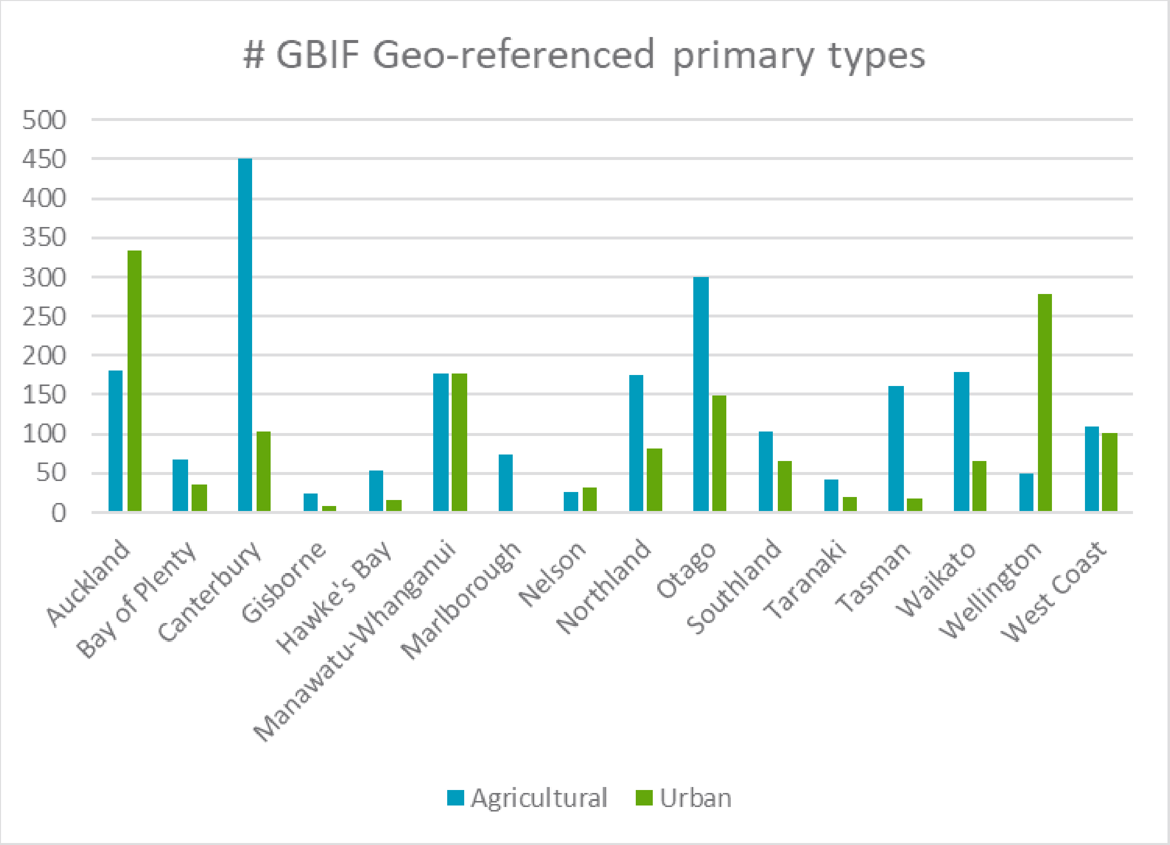

**Figure 5. Regional breakdown of numbers of types in modified habitats.**

Figure 5 demonstrates the possibility that land-use change has affected type localities most significantly in the agricultural landscapes of Canterbury and Otago. Auckland, Manawatū and Wellington lead the pack for type localities in urban environments. Neither result is surprising.

Figure 6 shows the regional breakdown of type localities classed as wetland under LCDB5.

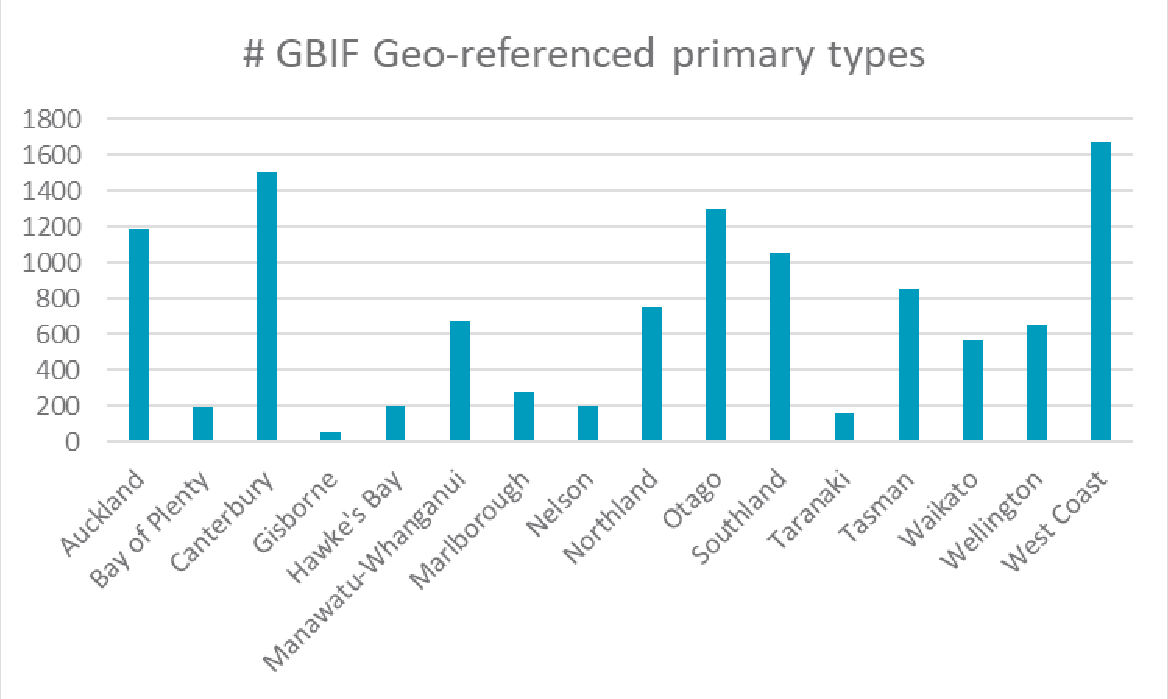

**Figure 6. Regional breakdown of number of types in wetlands.**

### 7.3.3 Type localities associated with at-risk or threatened species

We felt it would be instructive, from the perspective of designating SNAs, to examine the regional relationships between the primary type data and species that are currently listed under the NZTCS as at-risk or threatened. Here it is important to note that deriving these data relies on cross-linking the GBIF data with NZOR identifiers, and then using those identifiers to link to the NZTCS classification data. That process is associated with significant issues, as we reported earlier.

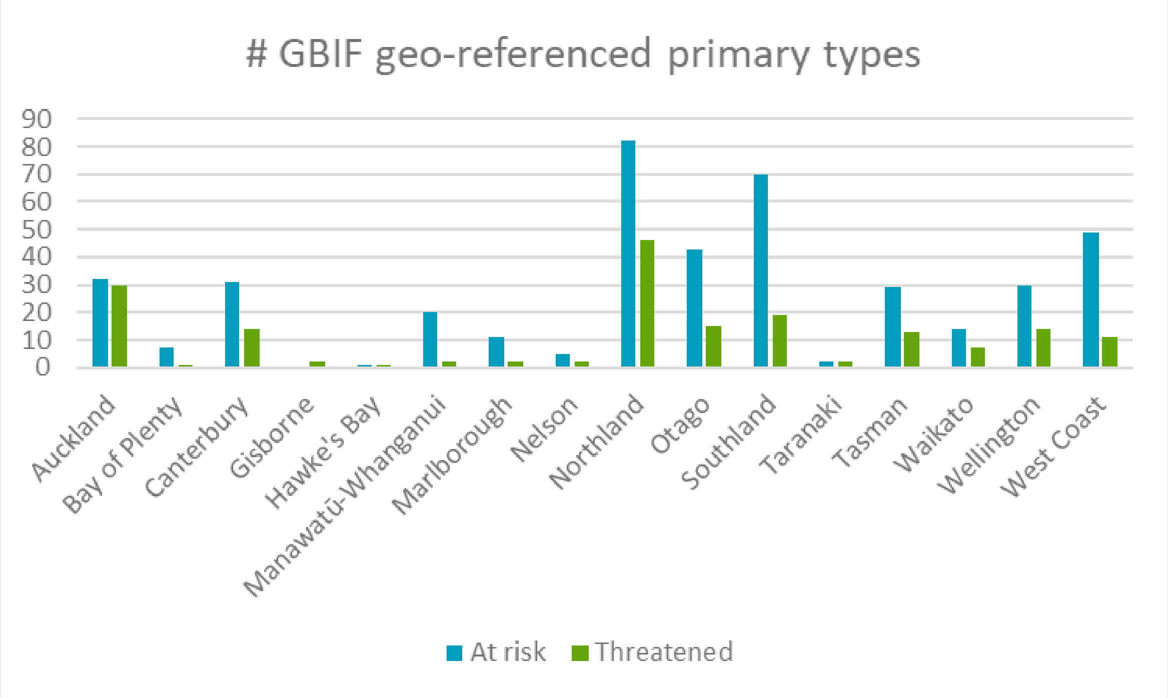

**Figure 7. Regional breakdown of number of types associated with NZTCS at-risk/threatened status.**

Northland and Southland have relatively high numbers of NZTCS-listed species, but we must stress that these data may be unrepresentative of the real totals for these areas.

### 7.3.4 Estimating the total number of potential New Zealand primary type localities

To estimate the total number of type localities we need to enumerate all the species that have been described from New Zealand, and no such list exists. However, we do have estimates of the numbers of species that are considered endemic (known only from New Zealand), or indigenous (endemic or also naturally present overseas). These figures can be derived from the NZOR, where species are flagged as endemic, indigenous or uncertain.

We know that all endemic species must have New Zealand types, and that some proportion of non-endemic but indigenous species will also have a New Zealand type. The downloaded NZOR data set contains 32,372 species listed as endemic, which doesn’t agree exactly with the statistics summarised on the NZOR website, where it indicates 23,935 endemic species from a total of 37,982 endemic/indigenous species. Nevertheless, we can estimate that between 30,000 and 40,000 species have been named from New Zealand and may have associated type localities.

We can derive accurate statistics for plants. The BiotaNZ names database contains complete and accurate information on biostatus. That tells us that we currently have 4,056 species regarded as indigenous and 2,651 species regarded as endemic. From this we can estimate that the number of New Zealand plant types is between these two figures. The current GBIF data report primary type information on 3,127 species. From this we can deduce that there is at least some type information already available for the majority of plant species, and a detailed review suggests just 14% of species are missing.

Our download of GBIF primary type data contains information on around 15,000 names in total across all groups. We can therefore estimate that only about 50% of type data are available via the GBIF (and flagged as types). Of the species for which there is no GBIF type data, about 82% are Animalia (with 57% Arthropoda), 14% Plantae, and 4% Fungi. It is, however, worth stressing once again that issues with NZOR data (incomplete coverage, duplication of entries and uncertain name status) makes these statistics quite uncertain. From inspection of the data we can be reasonably certain that most undigitised type data relate to arthropods/insects. Conversely, the data imply that completing the type locality for plants would be achievable.

## 8 Conclusions

Several conclusions can be drawn from this project. We can estimate that there are between 30,000 and 40,000 species named from New Zealand. Only a proportion of these named species will be associated with primary types, and in turn only a proportion of those will be associated with a type locality with any significant modern meaning or precision. This is the subset of type localities of relevance to SNA designation. As part of a prioritisation exercise we recommend de-prioritising species that were named before 1940, together with highly mobile and marine species. From the existing data we can estimate that perhaps 20,000 species will fall into this category. The number of species could be further reduced by considering those with an NZTCS classification other than ‘Not Threatened’.

We have basic digital data on about half of these species, and a substantial proportion are associated with a geo-referenced locality. We know that the existing data contain much duplication and error that need to be resolved. We know that only a small proportion (13%) of existing records are associated with some measure of uncertainty or bounds in geo-referencing, and that missing uncertainty/bounding data are vital for any application of type localities to SNA designation. We can infer that a substantial proportion of the missing data are associated with invertebrate species. On the other hand, the type locality information for plants is relatively rich and the completion and validation of these data achievable.

From our exercise in developing a catalogue of fern type locality data we have some approximate estimates for the times involved in locating relevant data, digitising that data, resolving issues, geo-referencing, and estimating geo-reference uncertainty. Putting all this together we can arrive at a very approximate breakdown of costs and activities for developing a complete digital catalogue of all relevant, prioritised, New Zealand type localities (Table 4).

**Table 4. Rough estimates of activities for a new type locality catalogue**

| Activity | Estimated no. of records | Total time (hours) | Operational costs |
|---|---|---|---|
| Number of literature protologues to scan/capture | 20,000 | 3,000 | |
| Librarian time estimate (non-digital accessible content) | 3,000 (estimate of articles required) | 500 | |
| Inter library loan/retrieval costs | 3,000 | | $150,000 (based on c. $50 per item) |
| Verification of extant GBIF type localities | 15,000 | 1,500 | |
| Addition of uncertainty to GBIF type localities | 13,000 | 2,500 (dependent on optimised digital portal availability) | |
| Location/digitisation of missing type specimen label data | 10,000 | 5,000 | $10,000 |
| Geo-referencing and uncertainty | 10,000 | 2,000 | |
| | **Totals** | **13,600 hours** | **$160,000** |

A project of the scale outlined in Table 4 is likely to be prohibitively expensive, at least as a national-scale project. The progress that has already been made, and which is apparent through the data already available in the GBIF, suggests a targeted and strategic approach is appropriate. Inclusion of all animal group would cover significant data gaps, but a focus on specific and relatively small groups, perhaps of significant conservation importance, is achievable. The digitisation of data associated with plant types is well advanced and so a complete kingdom-level catalogue for plants would also be achievable.

Institutional custodians of type collections within New Zealand should be supported to continue digitising type specimens as a priority. In particular, institutions currently not supplying data to the GBIF should be supported and encouraged to do so, and to adopt the well-defined available biodata standards. All holders of data should be encouraged to adopt best practice in capturing type locality data, and much more focus should be given to capturing locality uncertainty data. Clearly the NZOR has a vital role in projects such as this and needs greater financial support.

Accurate information on the occurrence and distribution of species is essential for all aspects of biodiversity and biosecurity management. In the case of type locality data, we have shown through some simple analyses of existing data that type locality information can provide useful insights into biodiversity management, including at-risk and threatened species, and type localities that may be at risk (or already lost) due to land-use change.

## 9 Recommendations

Any future project on type localities (at a national or regional scale) supporting SNA designation should incorporate the taxon priorities we have highlighted for identifying and digitising the missing type locality data. Any national-scale targeted project should have a taxonomic focus, and we recommend completing the national catalogue of plant type localities and perhaps other relatively small taxon groups. A further target would include NZTCS-listed species.

A common-access geo-spatial digitisation portal with appropriate GIS layers could significantly improve the efficiency of verifying/capturing point localities and associated uncertainty, as well as providing a dedicated search and display portal for the resulting data. In this respect it is worth considering other areas that would benefit from a restricted-access geo-portal; for example, the collation and display of threatened species data, otherwise mostly only available with obscured localities.

Existing GBIF data are only marginally fit for purpose for identifying type localities and typified names. In New Zealand we have limited ability to influence the quality of data provided to the GBIF from overseas institutes, but we can improve the extent and quality of the data we mobilise from organisations within New Zealand.

The people with significant expertise in interpreting type localities include the specialists in those taxonomic groups. This includes taxonomists and collection managers/technicians working in several institutes, and also includes those without a professional or institutional base. This distributed workforce should be considered in any future project.

The broader use of type locality data (and indeed any national-scale biodata) is critically dependent on our ability to easily cross-link information between different systems/databases. That process should be facilitated by the NZOR, but, as we have seen, the NZOR has issues around both the content and the supporting IT infrastructure. If we wish to facilitate the national-scale use of biodata in projects such as this, the NZOR and its data-provider network need to be enhanced and adequately supported financially.

It is important to note that this must include the essential support necessary for maintaining the information content of nomenclatural/taxonomic and specimen databases, as well as the IT infrastructure to mobilise those data. It is essential that, at the very least, New Zealand maintain a national list of species present in New Zealand, their alternative names, basic publication data, biostatus, and supporting evidence.

A national-scale type locality database focused on taxonomic groups of elevated significance would provide valuable data for taxonomic research and biodiversity management.

## Appendix – The GBIF data on New Zealand types

Data on species occurrence records from New Zealand associated with type specimens were extracted and downloaded on 1 August 2024. The requested data are in the Darwin Core Archive (DWC-A) format, which incorporates any available specimen type status data. The DWC-A file is available at https://doi.org/10.15468/dl.7dynh3

Information on type status forms part of the Darwin Core data standard:

> TypeStatus http://rs.tdwg.org/dwc/terms/typeStatus A list (concatenated and separated) of nomenclatural types (type status, typified scientific name, publication) applied to the subject.

However, it is clear from the downloaded data that the field is used rather loosely and often does not follow the recommended practice of forming a concatenation of data, including the typified name, which are critical data. For this reason it has been proposed that a separate field be implemented within the DarwinCore called TypifiedName, and indeed some data sets include this field.

Precisely how type data are mobilised is part of an ongoing discussion[29] by members of TDWG, with some suggestions (e.g. as part of an Identification extension to DarwinCore) potentially rather complex to unravel. For this project we have only analysed the content of the TypeStatus and TypifiedNames fields, where available, and we suggest that anything more complex is likely to be overlooked or dismissed by the average user of GBIF data.

The GBIF query filter used to extract data was:

> Country or area = New Zealand; Occurrence status = present; Type status = Type, Cotype, Epitype, Ex-epitype, Ex-holotype, Ex-isotype, Ex-neotype, Ex-type, Hapantotype, Holotype, Isolectotype, Isoneotype, Isosyntype, Isotype, Lectotype, Neotype, Syntype, Not a type

This query extracts data on just primary types and specifically excludes paratype. The query extracts data from 427 data sets in 23 countries. GBIF, and the original data providers, require that each data set be cited, and the GBIF exported list of data providers is cited here.

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[29] https://github.com/tdwg/dwc/issues/28

**GBIF Data sources providing information on New Zealand type specimens.**

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Agriculture and Agri-Food Canada (2024). Canadian National Mycological Herbarium. Occurrence dataset https://doi.org/10.15468/dchmcy accessed via GBIF.org on 2024-08-01.

Ahlstrand N E I (2024). NHMD Vascular Plants Collection. Natural History Museum of Denmark. Occurrence dataset https://doi.org/10.15468/4zygkn accessed via GBIF.org on 2024-08-01.

Ahyong S T, Farrelly C A, plazi (2018). First Australian records of Ethusina (Crustacea: Decapoda: Ethusidae) and additional records from New Zealand. Plazi.org taxonomic treatments database. Checklist dataset https://doi.org/10.11646/zootaxa.4486.2.5 accessed via GBIF.org on 2024-08-01.

Ahyong S T, felipe (2019). The Cymonomid Crabs of New Zealand and Australia (Crustacea: Brachyura: Cyclodorripoida). Plazi.org taxonomic treatments database. Checklist dataset https://doi.org/10.3853/j.2201-4349.71.2019.1682 accessed via GBIF.org on 2024-08-01.

Ahyong S T, plazi (2019). Discovery of the sponge-associated caridean genus Paralebbeus in New Zealand and southeastern Australia: P. pegasus sp. nov. (Crustacea: Decapoda: Thoridae). Plazi.org taxonomic treatments database. Checklist dataset https://doi.org/10.11646/zootaxa.4652.2.10 accessed via GBIF.org on 2024-08-01.

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Australia's Virtual Herbarium (2023). National Herbarium of Victoria (MEL) AVH data. Occurrence dataset https://doi.org/10.15468/rhzrxw accessed via GBIF.org on 2024-08-01.

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Bakker F, Creuwels J (2024). Naturalis Biodiversity Center (NL) - Hymenoptera. Naturalis Biodiversity Center. Occurrence dataset https://doi.org/10.15468/jgywgc accessed via GBIF.org on 2024-08-01.

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