Scientific collections principles

Executive summary

Queensland's rich biological, geographic, and cultural diversity is unique and underpins potential insights to solving some of our biggest challenges. Queensland has a proud history of scientific investigation and collection. Conservatively, more than 4 million scientific objects are housed in nine state scientific collections across the state. These collections enable researchers, industry, and the wider scientific community, to study and compare historic natural ecosystems with present-day ecosystems. Technological advances, such as genome sequencing and online metadata sharing, are unlocking the additional scientific value held in these collections, aligning their sustained existence with Queensland's goals in science, education, and the economy.

Three of the Queensland's state scientific collections have statutory requirements, legislating particular obligations as part of current and future operation. Specifically, the

- Queensland Museum Network is named as the receiving entity of animal material under the *Biodiscovery Act 2004*.
- Queensland Herbarium is named as the receiving entity of plant and fungi material under the *Biodiscovery Act 2004*.
- Under the *Petroleum and Gas (Production and Safety) Act 2004*, petroleum tenure holders are required to lodge a sample with the state, which is held at the Geoscience Reference Collection.

Additionally, the *Biosecurity Act 2014* refers to, in connection to the Queensland Museum Network and the Queensland Herbarium, "any government entity with expertise in the identification of the restricted matter". Therefore, the expertise and work connected to the Queensland Plant Pathology Herbarium and Culture Collection (BRIP) have statutory obligations.

Principles are proposed to support Queensland's scientific collections and to underpin their continued relevance into the future:

- Making informed decisions based on value and cost, consistent with the REDS (Real future impact; External commitment; Distinctive angle; Scaling towards critical mass)[1] decision rules for investment to ensure effective management of collections and targeted and impactful investment.
- The need for strategic alignment, based on scientific expertise, physical storage requirements, management methodologies, and the value, significance, and overall impact of actual collections.
- Use of sustainable funding models, including commercial or fee-for-service options
- Use of active protocols for making collections more available, including significant progress in digitising samples, or making data available via the Atlas of Living Australia.

As many scientific collections have grown over time, funding and capacity for appropriate storage and management have proven problematic and have often resulted in *ad-hoc* and substandard storage with little or no opportunity for the inclusion of new samples[2]. Inconsistent curation

[1] Office of the Queensland Chief Scientist (2018) Decision rules for investment (REDS). Queensland Government. https://www.chiefscientist.qld.gov.au/strategy-priorities/decision-rules-for-investment

[2] Australian Academy of Science, Royal Society Te Aparangi (2018), Discovering Biodiversity: A decadal plan for taxonomy and biosystematics in Australia and New Zealand 2018-2027. https://www.science.org.au/files/userfiles/support/reports-and-plans/2018/taxonomy-decadal-plan-lo-res-v200618.pdf

standards, often dependent on the perceived significance or value of collections, poses a risk not only to the integrity of items housed in the collections themselves, but also the integrity of data collected, and conclusions drawn in scientific studies. Collections without consistent curation standards also cannot be widely utilised in comparative studies. The changing cultural landscape demands agility in scientific collections – the definition of 'essential research' may change over time, depending on the views and needs of all Queenslanders.

Despite these challenges, the size, diversity, and scope of Queensland's scientific collections provide a unique opportunity to build on their historic and contemporary value and to maximise their impact. Some options are proposed:

- Improve storage – optimising use of existing and/or combining collections of similar specimens or similar research themes will enhance comparative research and create potential for new synergies to emerge.
- Education and research – the nexus between education and R&D providers could provide greater opportunities to use collections for educational or research purposes.
- Digitisation – using digital technologies to create cyber records of physical specimens and to better connect physical specimens with metadata, enabling greater cross-referencing and cataloguing for easier future research.
- Financial partnerships – commercial entities and scientific collections (in collaboration with universities) may form synergistic partnerships with mutually beneficial outcomes, to help unlock full potential.
- Online presence and digital platforms – promote cross-institution information sharing to encourage greater scientific collaboration and increased public access to digital collections to increase Queenslanders engagement in science.

1. Context and need

Queensland is the most biodiverse state in Australia and is home to a range of environments and ecosystems. However, Queensland is also a state that is increasingly experiencing more severe natural disasters – from fires to floods and tropical cyclones. A comprehensive understanding of the history, current state and potential future changes in Queensland relies on the strength of its research community and the scientific collections they use. These collections are essential to understand, evaluate and re-evaluate scientific findings: from the geological or geomorphological history of Queensland, temporal changes in biodiversity, biodiscovery of novel drugs and compounds, to informing and protecting agricultural industries from incursions of exotic pests.

Improved utilisation of scientific collections would allow for future growth of multiple emerging industries, especially in the environmental sector, and facilitate easier interactions between science and administration. In 2018, the Australian Academy of Science, together with the New Zealand Royal Society Te Aparangi, published the Decadal Plan for Taxonomy[5] which aims to improve the situation of taxonomic research by 2028.[3] The plan describes six initiatives, all of which would be addressed through the application of the proposed principles. The plan clarifies the need for strong taxonomic capabilities and this policy would allow Queensland to be an early adapter of globally needed reforms.

2. Scope and objectives

A range of potential opportunities exist to guide informed decision-making about how the State's most valuable scientific collections are maintained to deliver the maximal scientific impact and enhance the lives of all Queenslanders. These opportunities are guided by the definition of high-level principles that define the scientific, social and economic ideal outcome. Furthermore, the project aims to better communicate the merits of scientific collections through a unified approach in describing their significance.

Following the six initiatives postulated by the Decadal Plan for Taxonomy[5], the Office of the Queensland Chief Scientist envisions a comprehensive scientific collections policy that standardises and unifies the management, operation, maintenance, and support of scientific collections across the state. This approach would create a system with numerous benefits:

- A system of interconnected collections, all of them adhering to international standards
- The definition of processes creates accountability on every level of management
- The definition of standards showcases weaknesses and strengths and allows for a targeted approach in fixing issues
- Collaborative use of space and/or work
- Increased public awareness and value placed on collections
- Greater use and interest
- A rationale for potential support on an ongoing basis.

3. The importance of scientific collections

[3] Australian Academy of Science, Royal Society Te Aparangi (2018), Discovering Biodiversity: A decadal plan for taxonomy and biosystematics in Australia and New Zealand 2018-2027. https://www.science.org.au/files/userfiles/support/reports-and-plans/2018/taxonomy-decadal-plan-lo-res-v200618.pdf

On a global scale, most of our current knowledge about the earth's history is based on scientific collection-based research. The work of museums in curating, restoring, and examining their collection items lets us know about the existence of dinosaurs, the severity of our current climate crisis and how humanity came to be. Scientific collections are simultaneously storehouses to preserve valuable biological, geological, and other scientific items in perpetuity, and active, agile research centres providing insights into the physical and biological world as new technologies create new research opportunities.

3.1. Legal Obligations

The United Nations Convention on Biological Diversity (CBD)[4] in 1992 has changed the way society is supposed to interact with nature. Whereas many collections were established under the premise that natural resources were public property, the CBD introduced the concepts of conservation, sustainable use, and fair and equitable sharing.

Queensland legislation that assists in meeting the CBD obligations include the *Environmental Protection Act 1994*, the *Nature Conservation Act 1994*, and the *Biodiscovery Act 2004*. The latter of these acts defines the legal obligations of anyone wanting to collect specimens from State land or Queensland waters or to use traditional knowledge in biodiscovery for commercial use.[5] Furthermore, it names the Queensland Museum and the Queensland Herbarium as receiving entities for collected items, providing a legal necessity for these scientific collections.

Additionally, the *Biosecurity Act 2014* and the *Petroleum and Gas (Production and Safety) Act 2004* both reference the need for expertise in both storage and identification of samples.

In 2011, the United Nations supplemented the CBD with the Nagoya Protocol[6], further defining the concept of fair and equitable sharing. The protocol requires that consent be obtained for the utilisation of resources, and that benefits are shared on mutually agreed terms. It also emphasises the rights of indigenous populations to have a fair share of the benefits arising from use of biological resources from their land or where their knowledge is used. It does not differentiate between commercial or scientific use or distinguish state land from private land.

Demonstrating compliance with the protocol is rapidly becoming a prerequisite to operating in, or collaborating with partners in, Nagoya Protocol compliant countries. To foster international collaboration and in recognition of the rights of first nations peoples, in September 2020 the Queensland Government introduced amendments to the *Biodiscovery Act 2004* to improve alignment with the Nagoya Protocol. A key amendment was the introduction of a new obligation for the use of traditional knowledge in biodiscovery. The traditional knowledge obligation requires that a person takes all reasonable and practical steps to only use traditional knowledge for biodiscovery with the agreement of the custodian of the knowledge.

The *Biodiscovery Act* only applies to material collected from State land or Queensland waters, and further, does not apply if the collected material is used:

- to classify the material scientifically (such as for taxonomic purposes)
- to verify research results concerning the material

[4] United Nations (1992), Convention on Biological Diversity. https://www.cbd.int/doc/legal/cbd-en.pdf
[5] Queensland Government (2004), Biodiscovery Act 2004. https://www.legislation.qld.gov.au/view/whole/html/inforce/current/act-2004-019
[6] United Nations (2011), Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits arising from their utilization to the Convention on Biological Diversity. https://www.cbd.int/abs/doc/protocol/nagoya-protocol-en.pdf

- by an educational institution, or a person at the institution, for educational or training activities not involving commercialisation of the material.

Therefore, many, if not most activities undertaken by scientific collections, would not be applicable under the Act.

3.2. Jurisdictional analysis

In the Australian context, it appears that no state or territory has a comprehensive and overarching scientific collections policy. Extensive consultation revealed that approaches used in other Australian jurisdictions tended to be tailored to each collection, enabling targeted curation based on needs and requirements (**Table 1**).

Table 1: Approaches used for scientific collections by other Australian jurisdictions.

Jurisdiction	Scientific Collection Policy
Australia	**CSIRO** - On a national level, CSIRO has a number of scientific collections under its care.[7] CSIRO also hosts the Atlas of Living Australia (ALA),[8] funded by the National Collaborative Infrastructure Strategy (NCRIS). The ALA provides Australian collections with the opportunity to combine their collections in one large online database. Consultation revealed that the current funding of the ALA is at risk for the continuous and expanded data services. The expansion of the service to non-living specimens (palaeontological specimens) has been discussed and is part of future planning, pending the necessary funding.
NSW	**Australian Museum** – The ALA was viewed as the main portal for their natural history information, handles bulk queries and downloads, and importantly, contextualises specimen data with what is available from other states. The diverse nature of state collections, including type of specimen, data needs, storage requirements, and cultural significance warrant a diverse suite of collection management skills. In the wider Sydney area, the "Project Discover" is currently underway, trying to rationalize storage needs for the Australian museum, in order to make them more commercial and provide for a larger exhibition space.[9] Create NSW, within the Department of Planning, Industry and Environment have been undertaking major reviews of state collections storage, both physical and virtual. The project highlighted the different needs of collections, concluding that individual management solutions are ideal. However, the project ended prematurely and did not resolve the underlying issues identified.
NT	The Museum and Art Gallery Northern Territory follows international standards on Museum collection management. No evidence for further scientific collection management in the state.
SA	In coordination with the state Museum and Herbarium, the Biological Databases of South Australia (BDBSA) organize biodiversity and scientific data online. The database has a connection to the ALA.[10]

[7] CSIRO (2020) National Research Collections Australia. https://www.csiro.au/en/Research/Collections
[8] CSIRO (2020) ALA. https://www.ala.org.au/
[9] Australian Museum (2020) Project Discover. https://australianmuseum.net.au/blog-archive/explore/explore-magazine-project-discover/
[10] South Australia Department of Environment and Water (2020) BDBSA. https://www.environment.sa.gov.au/topics/Science/Information_data/Biological_databases_of_South_Australia

TAS	The Tasmanian Museum and Art Gallery follows international standards on museum collection management. No evidence for further scientific collection management in the state.
VIC	The National Herbarium of Victoria, located at the Royal Botanical Gardens in South Yarra, is one of the first institutions to utilize the 'Significance 2.0'[11] method of the Australian Collections Council to further justify the necessary funding for their collection. This method, combined with regular financial assessments, has enabled the Australian Herbarium to attract funding.
WA	The Western Australia Biodiversity Science Institute (WABSI) has started a practice of collecting and publicly sharing Environmental Impact Assessment Data[12], providing a combined value of currently $60 million to the public. This practice can be transferred to the data stored in scientific collections, which are useful for future EIAs across Australia.

4. Principles

In order to assess the long term sustainable and full scientific usage of our state scientific collection, the following four overarching principles are proposed as potential benchmarks. These principles align with processes that are utilized by exemplars of scientific collections around the planet.

4.1. Making informed decisions based on value and cost

Informed decisions are based on fact. Decisions about the future of collections need to made objectively and determined by benefit and cost. Determining the value of collections and evaluating merit is fraught with difficulty, and this subject is explored in further detail in Section 6 (Evaluating state scientific collections).

As part of the science and research priorities, the Office of the Queensland Chief Scientist has proposed a set of rules to guide public investment (REDS)[13]. The REDS decision rules were developed to ensure R&D investments are targeted and impactful and can be used to assess an entire portfolio or a single project. Applying the REDS to a scientific collections or a particular specimens, the four criteria determining investment are:

- Real future impact – Does the collection have a real positive impact (economic, environmental, social) for Queensland?
- External commitment – Is there external collaborative partners and end-users committed to the collection, and is the share of external contributions likely to increase over time? How do external scientists or the public interact with the collection?

Once a tree is removed from its environment, it is often hard to identify the provenance of a certain product. Wood samples at the Wood Reference Collection are used to help with these identifications. For example, the Queensland Police Service Ballistic Unit has been assisted in identifying old and handmade weaponry.

Picture 1: Gaz Hopewell (2015), identifying an old rifle

[11] Context Pty (2016) STATE BOTANICAL COLLECTION SIGNIFICANCE ASSESSMENT Royal Botanic Gardens Victoria. https://www.rbg.vic.gov.au/documents/SBC_Significance_Assessment_FINAL_29.11_.16_.pdf

[12] WABSI (2020) Digitally Transforming Environmental Impact Assessment. https://wabsi.org.au/our-work/projects/digitally-transforming-environmental-impact-assessment/

[13] Office of the Queensland Chief Scientist (2018) Decision rules for investment (REDS). Queensland Government. https://www.chiefscientist.qld.gov.au/strategy-priorities/decision-rules-for-investment

- Distinctive angle – What is in it for Queensland, and why is Queensland the place to have this collection? Does it provide a unique voice to related sciences?
- Scaling towards critical mass – Is there action to further improve and increase the value/significance of the collection? [14]

4.2. Strategic Alignment

Strategic alignment is important to ensure Queensland scientific collections are synergised and maximise scientific and other benefits to the community. In scope is the alignment of scientific expertise, physical storage requirements, management methodologies, and the value, significance, and overall impact of actual collections.

Following national and international best practice, the following common practices are possible:

- Existing and new collection space have to be assessed for suitability, with collaborative approaches and shared spaces between collections as the standard approach
- Accession and De-Accession of items should be benchmarked based on value, either as individual pieces or as part of the collection – with periodical reviews of accessed items
- Infrastructure and technology, i.e. valuable equipment, should be shared between collections and, if possible, collaboration with state government agencies arranged

4.3. Sustainable Funding models

Most collections currently suffer from a lack of funding. A need exists for creative economic approaches to collection management. This way a sustainable future for each collection, considering the proposed increase in taxonomic importance in the future, can be achieved. Whereas all collections are built on the principle of free data sharing, a sophisticated approach to commercialisation could help to ease funding challenges.

While the individual approach is dependent on the circumstances of the individual collection, the following practices are possible:

- Commercialisation through sophisticated contracts with external stakeholders, focussing on the biochemical abundance of novel components found in scientific collections
- Access and handling fees for commercial clients
- Financial approach to data sharing with commercial entities, e.g. for Environmental Impact Assessments as environmental benchmark materials

4.4. Increasing the availability and use

This principle is about making collections available for use by other scientists or accessible by the public. One of the main issues identified through this review is the lack of knowledge about individual state scientific collections. Even within the scientific community, the existence of some collections is not widely known or understood, reducing their scientific value and utilisation. Therefore, one should use active protocols for making collections available to the public.

While there is no simple answer to increase the public availability of a collection without decreasing its scientific value, some practices are possible:

[14] CSIRO (1999) *Mytilopsis sallei.* https://www.scienceimage.csiro.au/tag/molluscs/i/961/mytilopsis-sallei-black-striped-mussel/

- Increased online presence through multiple channels (social media, official websites)
- Targeted educational marketing towards high schools and undergraduate university courses, ideally with direct collaboration and potential offer of educational tours/volunteer opportunities
- National digital collaboration through the ALA

A review using these four principles in a fixed time frame would allow for an adequate understanding of the impact, positive or negative, of any implemented changes. This approach keeps communication channels between administration and scientists open and demands accountability from both sides.

5. Evaluating state scientific collections

Evaluation of scientific collections is often challenging but is instructive in determining how these assets may be managed in the future.

5.1. Potential evaluation criteria

For consideration, four criteria may be considered to approximate the value of Queensland's scientific collections:

1. The average monetary value of the collection (per item)
2. The average maintenance cost (per item)
3. The level of access to the collection
4. The significance of the collection as a whole

Each of these criteria are considered in greater detail in the sections below.

5.2. Monetary value

Monetary value is a simple metric often used in collections throughout the world. It is common practice to use a combination of the recovery cost, the maintenance cost, and the market rate as a value. As this process is very cost-intensive, such measures are only taken by larger collections for insurance purposes. For example, the Queensland Museum Network values its cultural and scientific assets every year[15]. Valuation of smaller collections may be conducted using less rigorous methodology. The Council of Australasian Museum directors recently (2018) published a Collections Valuation Framework[16] which defines how monetary collection valuation should happen, which forms the basis of the evaluation of the museum. Due to the lack of access to a professional valuation for each collection, an approach of equivalence will be used.

5.3. Maintenance cost

The second valuation methodology compares collection value versus maintenance costs. These costs include staffing, building maintenance, energy, and supplies and services. Larger collections may present this valuation technique in annual reports to stakeholders. However, smaller scientific

[15] Board of the Queensland Museum (2019), Annual Report 2018-2019.
[16] Council of Australasian Museum directors (2018) Australian framework for the valuation of public sector collections for general purpose financial reporting. https://camd.org.au/files/2018/11/CAMD-Collections-Valuation-Framework-1-Nov-2018.pdf

collection maintenance is often included into the running costs of a specific department and therefore not specifically quantified.

5.4. Accessibility

The third valuation tool is the degree to which collections are accessed by external parties. Although collections are required to document each physical loan, requests for data are often done on an *ad-hoc* basis. Different types of access (*e.g*. academic, public, online vs in person etc.) can be considered individually.

Guidelines to rate the first three potential evaluation criteria are shown below (**Table 2**).

Table 2. A potential rating system for the first three evaluation criteria.

Grade	Monetary value ($/item)
1	<50
2	51-100
3	101-200
4	201-300
5	>300

Grade	Maintenance cost ($/item)
1	>20
2	19-10
3	9-5
4	4-1
5	<1

Grade	Access rates
1	<5 times a year
2	>5 times a year
3	At least once a week
4	Daily
5	Multiple times daily

5.5. Significance

The final evaluation tool proposed is meant to bridge the gap between the often-misleading financial viewpoint and the actual reasons collections are kept (*e.g*. scientific, educational and historical/cultural impact). This tool, which estimates the significance of the whole collection, was developed by the Collections Council of Australia (Significance 2.0) and has been used by the Victorian National Herbarium to publicise their significance[17] and justify further investment.

Following the guidelines in the Significance 2.0 report[18], each collection is measured against four significance criteria: historical, aesthetic, scientific and social. Each evaluation is summed up in one paragraph, giving an overview of the current importance of the respective collection. True to the original intent of the tool, no numerical value is given for this fourth criteria.

[17] National Herbarium of Victoria (2016), Significance Assessment https://www.rbg.vic.gov.au/documents/SBC_Significance_Assessment_FINAL_29.11_.16_.pdf

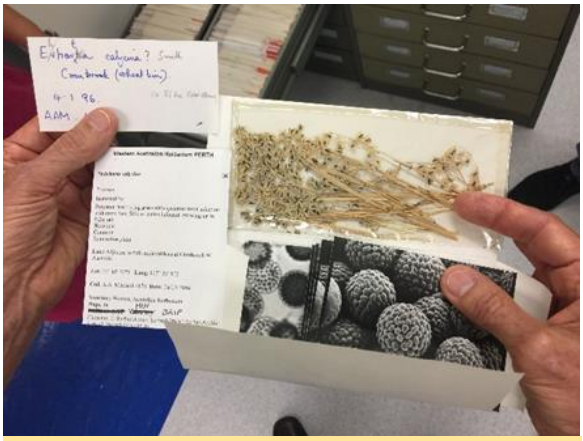
[18] Collections Council of Australia (2009), Significance 2.0 a guide to assessing the significance of collections https://webarchive.nla.gov.au/awa/20101122024352/http://pandora.nla.gov.au/pan/112443/20101122-1236/significance.collectionscouncil.com.au/index.html

The **Queensland Museum Network** has a 150-year long history, documenting the state's diverse and varied history. The collection is historically significant as it is the main source of understanding of the scientific history of Queensland. this significance lies in the future scientific potential of the collection. While most of the specimens have been collected to showcase the biodiversity of Queensland, past and present, new technologies have revealed new uses for the collection. As a place of pride and history, the museum has an important cultural role. Adhering to modern museum standards and collections practice, the collection has records on the providence of most of their collection specimen. Additionally, the Queensland Museum Network is defined as the receiving entity under the Biodiscovery Act 2004 to receive any animal material that has been collected on state land.

Specimens held in the Queensland Herbarium are assisting scientists to identify new species of hyperaccumulators, plants or other organism that accumulate often toxic chemicals and compounds. Only 0.2% of flowering plants are hyperaccumulators. Investigators from the University of Queensland are using herbarium specimens to identify new species that can be used for Phytomining toxic landscapes.

Picture 2: The New Caledonia tree Pycnandra acuminanta bleeds a latex exudate that contains 25% nickel. Image: Antony van der Ent, The University of Queensland

The **Queensland Herbarium (BRI)**, like the Queensland Museum Network, has a 150-year long history of research and collection of plant specimens. The existence of the BRI is evidence for the long history of scientific interest in the unique flora of Australia, combining collections from historically interesting figures with modern day collectors. BRI's scientific significance lies in its large catalogue of type specimens, close collaboration with other herbaria worldwide and the scientific potential of the stored specimens. The Herbarium is also used by Queenslanders through an onsite curation volunteer program and free plant and macrofungi identification services. Additionally, the Queensland Herbarium is defined as the receiving entity under the Biodiscovery Act 2004 to receive any plant or fungi material that has been collected on state land.



Picture 3: A sample of the fungus stored at the BRIP helped identify the fungus and avert a national disaster

In 2004, Pakistan authorities rejected the importation of two bulk carriers of wheat in the Port of Karachi. It was claimed that Karnal bunt fungus (Tilletia indica) had infected the wheat. Australian quarantine and wheat officials refuted the claims, based on evidence that the fungus was a different species that was present on grass in the wheat field. Saving the Australian wheat industry $35 million in lost exports[18]

The **Queensland Pathology Collection (BRIP)** has been the centre for microfungi and other plant pathogens research and identification since the early 20th century. Although BRIPs location and affiliation has changed throughout time, the focus of the collection has stayed the same. It holds immense scientific value as it enables for the early identification of plant pathogens, potentially saving millions in agricultural losses. Therefore, the collection holds a social value within the Queensland biosecurity and agricultural community. As the only government entity within Queensland to have this taxonomic knowledge, the collection is needed to identify restricted matter, as set out in the Biosecurity Act 2014.

The **Queensland Insect Collection**, housed together with the BRIP, has a similar history. It underwent multiple phases of interest and neglect, aptly describing the history of entomological interest in Queensland. The collection has scientific value as it houses significant amounts of agriculturally relevant insects. The collection offers valuable resources for the identification of biological options and development of integrated pest management for Queensland farmers who want to minimize their usage of pesticides. Although the Queensland Insect Collection has unique elements, such as a complete collection of agriculturally relevant fruit fly species, it is not the only insect collection in the state. Furthermore, the collection has connections to the biosecurity sector, but its interpretative quality for this purpose is hindered by a lack of funding and on-site expertise.

The **Aquatic Macroinvertebrate Collection** is a continuous reference point for changes in freshwater biodiversity and quality over the last three decades. The collection has high scientific value as it is the only complete representation of freshwater biodiversity in Queensland. Whereas other collections have elements in common, this collection connects species composition and water quality in a distinct body of water. Additionally, new technologies will enable future genetic research which may reveal crypto diversity. The relatively low historical significance and the lack of social significance outside of the direct group managing the collection diminishes the potential impact of the collection.

The **State Soils Collection** has been the repository for soils collected from various survey and research projects since the early 1970s. The soil samples provide historic reference points to the chemical and physical properties of soil across Queensland. However, most soil samples are derived from land resource surveys and research projects with specific aims, thereby limiting the representative and contextual value of the collection, since systematic sampling processes across all areas of Queensland is not featured. The State Soils Collection does offer scientific value as a record of Queensland's soil distribution. However, the collection is unique. There is a National Soil Archive held by the CSIRO but this stores a less diverse range of samples from Queensland.

The **Wood Reference Collection** is one of the largest and best curated xylaria in Australia. Xylaria were first conceived of in the 17th century, but in recent times, their value has become diminished.

Additionally, the Brisbane Xylarium has been used as a referencing catalogue for over six decades, identifying wood specimens throughout Queensland. Recent changes in priorities have deleted the interpretative quality of the collection on a state-wide basis. The Wood Reference Collection is both scientifically and culturally significant as it is one of the few remaining curated xylaria of Australia.

The **Geoscience Reference Collection** has curated core samples and geological data since the 1950s, along with earlier mining written records. The collection is historically significant as it has the most accurate accounts of mining endeavours throughout Queensland's history. Scientifically, the collection enables individuals to plan new mining operations safely and effectively. Cores were used to create a geological map of Queensland, which is continually being reassessed and refined, and are used to identify new resources and mining potential. New technologies, such as the HyLogger spectroscopic scanner and data storage principles, enable fast and effective analysis of geological samples. Therefore, the collection is highly regarded in both the research and economic geological communities. However, legal shortcomings, a lack of public interest, and various other problems have prevented the collection from becoming a complete representation of the mining landscape, past and present. Under the Petroleum and Gas (Production and Safety) Act 2004 a petroleum tenure holder is required to provide samples to the state. These are kept at the Geoscience Reference Collection.

The **Leptospirosis Culture Collection** is a laboratory that deals with a specific zoonotic disease, as part of a world-wide WHO program to monitor and manage potential outbreaks. As leptospirosis is a bacterial infection, knowledge, and management of it has a short history. However, scientifically the laboratory has a global responsibility to avoid unnecessary harm to humans from future infections. Therefore, the collection possesses high social significance due to its global connections. Although relatively small and usage highly dependent the incidence of Leptospirosis in the community, the unique scientific abilities and the widespread effects of its research are significant.

Appendix 1 State Scientific Collections Table

Collection	Responsible Staff	Location	Samples	Number	Value ($)	Current Maintenance ($/year)	Value/Maintenance (years*)	Storage	Access	Level of Access	Email	Online Access	Website
Queensland Museum Network State Collection (Biodiversity Collection & Geoscience Collection)	Dr. Terry Miller *Head of Geosciences, Biodiversity and Geosciences Program* Peter Denham *Director – Collections and Research*	Queensland Museum Corner Grey and Melbourne Streets South Brisbane Museum of Tropical Queensland Queensland Museum Collection, Research and Loans Centre Gerler Road, Hendra	Scientific Collection	14,000,000	??	44,000,000[1]	10.2	Various storage methods – depending on the specimen requirements. The storage facilities have recently been evaluated and the wet storage is being updated.	By arrangement For Researchers	Constant	discoverycentre@qm.gov.au geoscience.inquiry@qm.qld.gov.au	Museum website + ALA	https://www.qm.qld.gov.au/Collections/Biodiversity+and+Geosciences/Biodiversity+Collections#.XlWhRsgza70 https://www.qm.qld.gov.au/Collections/Biodiversity+and+Geosciences/Biodiversity+Collections#.XlWhRsgza70
			Parasitology	98,000	450,000,000[1]								
			Marine Invertebrates	94,000									
			Spiders	101,000									
			Crustacea	44,000									
			Molluscs	85,000									
			Insects	270,500									
			Fishes	38,500									
			Herpetology	87,000									
			Birds	31,500									
			Mammals	22,000									
			Tropical Collection	13,500									
			Geosciences	60,000									
Aquatic Macroinvertebrate Collection (DES)	Dr. Jonathan Marshall *Principal Scientist* Peter Negus *Senior Scientist*	EcoSciences Precinct 41 Boggo Road, Dutton Park 4102	Macroinvertebrates	3500	5,250,000[2]	87,500[3]	60	Storage in Ethanol in glass jars. Split between two locations due to storage quality issues.	For Researchers	Very rare	aquaticmacrocellectn@qld.gov.au	ORACLE, not publicly available	No
State Soils Collection (DES)	Dr. Evan Thomas *Science Leader* Stephen Potts *Director*	Resource Management Centre Meiers Road, Indooroopilly	Soil Samples	130,000	52,000,000[2]	20,000[2]	2600	Stored in jars and plastic bags. Recent problems caused the collection to be at risk. Satellite collections are in substandard spaces.	For Researchers	Very rare	soils@qld.gov.au	Through Qld Globe	No
Queensland Hebarium BRI (DES)	Dr. Gordon Guymer *Director* Dr. Gillian Brown *Science Leader*	Brisbane Botanic Gardens Mt Coot-tha Road, Toowong 4060	Plants, Algae & Macrofungi	880,000	145,000,000[1]	2,000,000[4]	72.5	Specimens stored in pressed form on acid free paper, or dried in boxes or in ethanol (depending on the specimen) Recent mold and storage issues resolved.	Public Access through arrangement	Constant	queensland.herbarium@qld.gov.au	ALA (inc. Australian Virtual Herbarium) Herbrecs (internal) WildNet	https://www.qld.gov.au/environment/plants-animals/plants/herbarium/specimens

Collection	Responsible Staff	Location	Samples	Number	Value ($)	Current Maintenance ($/year)	Value/Maintenance (years*)	Storage	Access	Level of Access	Email	Online Access	Website
Plant Pathology Herbarium BRIP (DAF)	Dr Roger Shivas *Senior Principal Scientist* Dr Kaylene Bransgrove *Senior Principal Scientist*	EcoSciences Precinct 41 Boggo Road, Dutton Park 4102	Dried Fungal Cultures	90,000	8,100,000[5]	180,000[3]	45	Stored in cabinets in plastic folders. Stored in -80°C freezers. Upkeep is problematic.	For Researchers	Constant	callweb@daf.qld.gov.au	DAF Collections website	https://collections.daff.qld.gov.au/web/herbarium.html07
			Living Bacterial Culture	1000									
			Living Fungal Cultures	23,000									
Queensland Insect Collection (DAF)	Dr Roger Shivas *Senior Principal Scientist* Dr Kaylene Bransgrove *Senior Principal Scientist*	EcoSciences Precinct 41 Boggo Road, Dutton Park 4102	Pinned Insects	1,600,000	169,422,000[5]	61,000[3]	2780	Stored in cabinets.	For Researchers	Rare	callweb@daf.qld.gov.au	DAF Collections website	https://collections.daff.qld.gov.au/web/herbarium.html07
			Mounted Insects	52,000									
			Insects in Alcohol	9000									
Wood Reference Collection (DAF)	Dr. Maryam Shirmohammadi *Principal Scientist*	Salisbury Research Facility 50 Evans Road, Salisbury 4107	Wood Block Samples	12,633	151,600,000[6]	23,000[3]	6590	Stored in safe cabinets. Collection is stored in two different places due to under-usage.	For Researchers	Rare	callweb@daf.qld.gov.au	DAF Collections website	https://collections.daff.qld.gov.au/web/woodcollection.html
			Timber Microstructures	4703									
Geoscience Reference Collection (DR)	Christopher Hansen *Senior Logistics Officer*	Exploration Data Centre 68 Pineapple St. Zillmere 4034	Drill Cores, Cuttings, Rock Samples	197,000	1,000,000,000,000[2]	2,410,000[3]	415,000	Stored in two locations in warehouses. Zillmere is at capacity. Documents stored at the facility are not kept in ideal conditions.	For Researchers	Constant	exploration.datacentre@dnrme.qld.gov.au	Through QDex	https://www.dnrme.qld.gov.au/__data/assets/pdf_file/0003/343758/exploration-data-centre.pdf
Leptospirosis Culture Collection (Qld Health)	Dr. Scott Craig *Laboratory Lead*	Forensic and Scientific Services 39 Kessels Road Coopers Plains 4108	Leptospira Cultures	300	250,000[1]	50,000[2]	5	Stored in -80°C freezers.	For Researchers with adequate containment facilities	Often	fss-mta-coordinator@health.qld.gov.au	Dep. of Health website	https://www.health.qld.gov.au/healthsupport/businesses/forensic-and-scientific-services/testing-analysis/diseases/leptospirosis

*: Calculation of how many years it takes for maintenance costs to equal estimated value of the collection, giving a qualitative measure for current scientific evaluation.
[1]: Professional evaluation [2]: Estimation by Curator; [3]: Estimation by author based on current FTE + approximation of additional costs; [4]: Estimation of cost by curator (2016); [5]: Estimation by author based on cost of similar specimen in other collections; [6]: Estimation based on similar specimen + additional costs for import of skilled labor;