Natural Science Collections Facility
SOUTH AFRICA

SUMMARY REPORT

2023

Assessment of Management and Curation Practices in South Africa's Natural Science Collections

A Natural Science Collections Facility (NSCF) Collections Assessment Report
prepared by the NSCF Hub Team, June 2024

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1 Background and purpose

1.1 Background and Purpose of the Iqoqwana Initiative

1.1.1 The Natural Science Collections Facility (NSCF) Overview

South Africa is home to approximately 100 natural science collections across 40 institutions, encompassing over 18 million specimens that represent around 100,000 species of plants, animals, and fungi. These collections serve as critical research infrastructure in taxonomy, which documents, organises, describes, and names species while recording their geographic distribution. This is crucial for research areas involving living organisms, including agriculture, fisheries, human health, ecological infrastructure protection, illegal wildlife trade enforcement, climate change adaptation, and indigenous knowledge systems.

Data associated with these specimens, such as identity, collection date, and locality, form part of this infrastructure. Integrated data sets across institutions provide insights into biodiversity distribution patterns, aiding decision-making. Recognised for its biodiversity, South Africa has a unique responsibility to conserve and sustainably use this wealth.

The Natural Science Collections Facility (NSCF) was established as part of the Department of Science & Innovation (DSI)'s South African Research Infrastructure Roadmap, and was formally launched in 2017. The NSCF is a network of institutions that hold major natural science collections, with a co-ordinating Hub hosted by the South African National Biodiversity Institute (SANBI).

The vision of the NSCF is **to enable sustainable, enriched life on Earth** by working as a dynamic network that values and recognises the African context, **to promote, upgrade and make accessible natural science collections and data for research and services.** Two of the main objectives of the NSCF are 1. Securing collections and making these accessible for research and capacity development and 2. Upgrading and expanding collection specimen databases, and making these openly accessible in an integrated way for research, biodiversity assessment and decision-making. It is in this context that an assessment of the collections and associated data at the institutions participating in the NSCF was undertaken in 2023.

1.1.2 Previous Assessments

Surveys of South Africa's natural science collections in 1998 and 2005 revealed issues in curation and storage, with a detailed physical assessment commissioned by the NRF in 2009-2010 confirming inadequate resourcing, staffing, and infrastructure. Problems included poor temperature control, lack of fumigation, and unsorted materials, with governance fragmentation and lack of national curatorial policies also noted. Post-2014, the NRF and DSI invested significantly in the collections, establishing the NSCF in 2017 to secure and enhance their use. The NSCF implemented a coordinated network model, developed a comprehensive collection management and curation manual, and conducted extensive training. The 2023 assessment, branded and named the "Iqoqwana Initiative", aimed to evaluate and improve collection management through community collaboration.

1.1.3 Aims and Objectives of the 2023 collections assessment (Iqoqwana Initiative)

The 2023 assessment aimed to evaluate the state of collections in order to identify areas needing investment or intervention for strategic planning, provide institutions with information on collection status for better resource allocation and reporting, and to catalyse the implementation of the NSCF Collection Management and Conservation Manual.

The process promoted action learning and capacity building, strengthening institutions through assessment outcomes, and enhancing networking and community-building within the NSCF.

The initiative was founded on strong principles in planning and strategising by adhering to principles of data credibility through consistent standards, capacity development by building staff skills, inclusivity and collaboration by engaging all staff, transparency through open assessment processes, and transformative impact by effecting meaningful change beyond mere reporting.

1.1.4 Methods and Approach

The Iqoqwana Initiative involved over two years of planning, consultation, and discussion. The process included self-assessments using a questionnaire with 185 questions, document submission, on-site moderation, data analysis, and compilation of feedback.

Pre-assessment sessions with directors and stakeholders outlined the self-assessment principles and tool specifics. Post-assessment sessions provided feedback and discussed analysis outcomes, guiding institutions through their feedback documents and planning future steps.

Feedback documents were compiled for 60 collections and 19 institutions, focusing on three main areas namely: i) risk management assessment, ii) implementation status of collection and data management practices as contained in the NSCF Collection

Management and Conservation Manual, and iii) extent of documents developed that are required for professional, scientifically credible practice.

1.1.5 Summary Report

This report summarises the state of South Africa's natural science collections at the time of the assessments in 2023. It provides an overview of the state of risk management, implementation of collection and data management practices, development of documentation and staffing status. The analysis methods are presented in Annexure 2.

2 Summary findings

2.1 Overview of the natural science collections included in the assessment

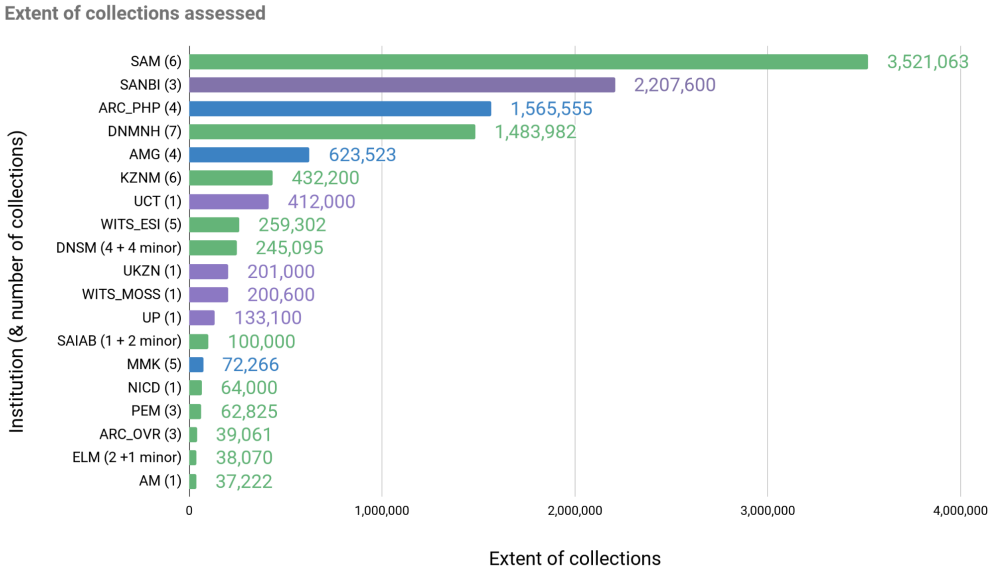


Figure 1. Number (shown in brackets after the institution name) and total extent of collections for the institutions included in the collections assessment. Purple bars represent herbaria, while green bars represent other collections. Extent of collections indicates the number of specimens, where applicable, specimen lots (i.e. a single catalogue number assigned to a container holding more than one individual specimen, and each specimen has the same collecting event details). Note that the Ditsong NMNH figure excludes the Coleoptera and Herpetology collections, and the Albany Museum figure excludes the Palaeontology Collection because these did not participate in the collections assessment process.

All 19 NSCF partner institutions participated in the collections assessments, collectively holding over 69 collections. These collections encompass over 11.7 million specimens/accessions, broken as down as 6.3 million entomology (insect) specimens / accessions, 4.3 million herbarium sheets, 770,000 palaeontology specimens / accessions, 720,000 non-insect invertebrates, and 624,000 vertebrates (mammals, birds, reptiles, amphibians and fish).

A comprehensive list of institutions included in the 2023 collections assessment is provided in Annexure 1 (including governance structure, main collections, overall size of collections and number of staff associated with the collections).

Seventeen collections are growing at a rapid rate, and 11 collections have high levels of use through visiting researchers and loans (Fig. 2). However, almost a third of collections are not growing, and a similar proportion has only low levels of use for research (Fig. 2). Those collections that are actively growing and have high levels of use are generally large and in institutions with a team of researchers and postgraduate students.

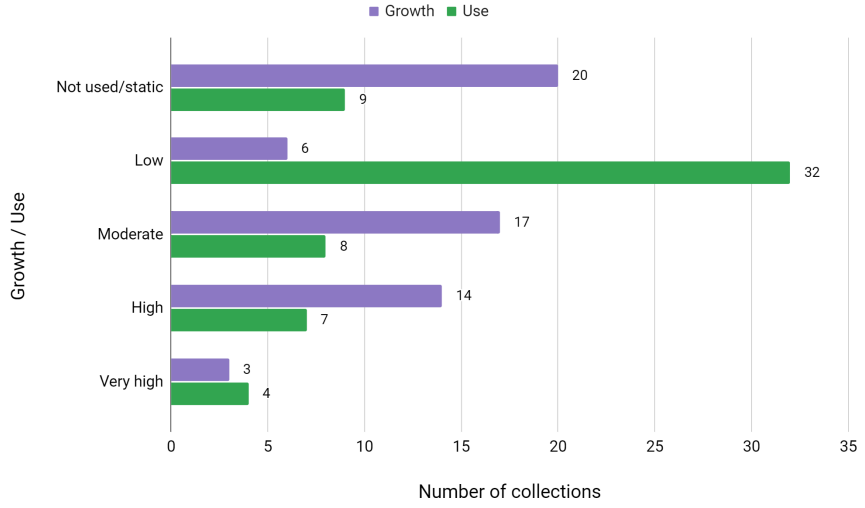


Figure 2. Levels of use and growth across the 60 collections assessed. Growth includes specimens added by researchers in the institution and through donations from external researchers, postgraduates or others. Use includes both visiting researchers and specimens sent on loan. The type of collection has been considered in categorising growth, and the combination of visitors and loans has been considered in categorising use level.

2.2 Securing and preserving collections: Risk mitigation and management

2.2.1 Risk mitigation/management across all collections

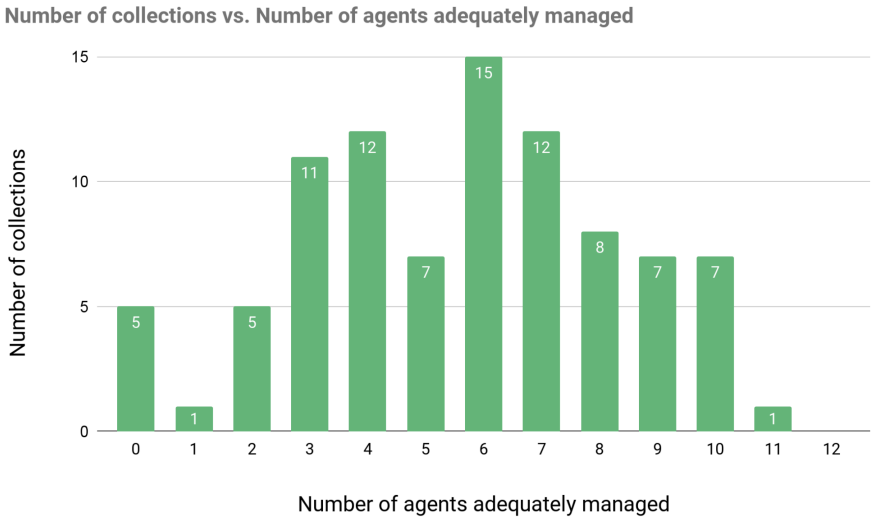


Figure 3. Number of agents of deterioration and destruction for collections that are adequately managed or mitigated (i.e. >66.67% of measures are in place) for 91 collections (wet and dry collections considered separately).

A structured approach was adopted to understand the extent to which risks to collection objects and associated data are managed or mitigated. This involved calculating standardised risk scores for various agents of deterioration and destruction and then evaluating the management and mitigation measures in place for each collection. The agents of deterioration and destruction included light/uv exposure, pests, fire, water damage, temperature, security, relative humidity, dissociation - loss of specimens, dissociation - loss of specimen data, physical forces and pollutants, dust and grime. For wet collections, fluid preservative levels were also assessed.

Five of the collections did not have any of the agents of deterioration and destruction adequately managed (Fig. 3). Twenty-three collections had adequate mitigation measures in place for eight to 11 of the agents, however the majority of collections were only managing seven or fewer of the agents adequately. The average number of agents adequately managed in both dry and wet collections were six agents.

2.2.2 Highest risks to collections

Not all of the agents of deterioration and destruction are equally severe, considering the likelihood of them occurring or the rate at which deterioration happens and the extent of the impact on individual specimens and the collection as a whole.

WET COLLECTIONS:

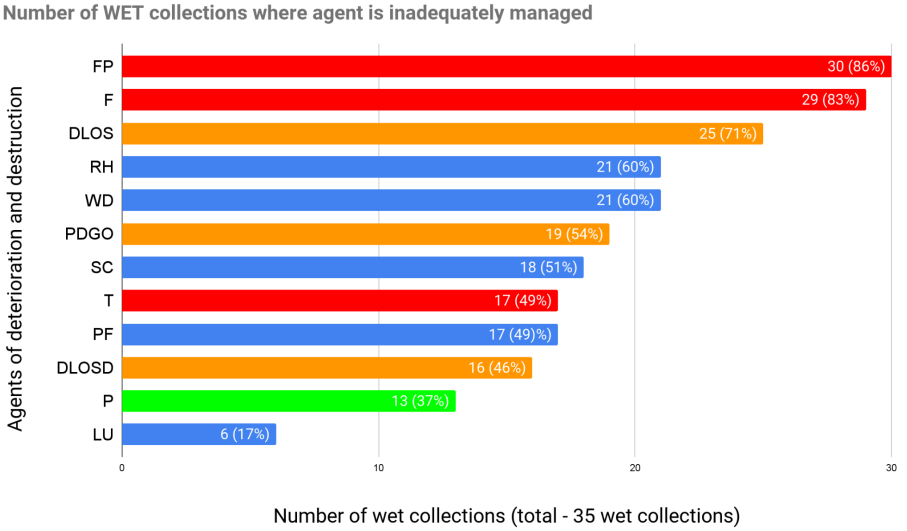


Figure 4. Number and (percentage) of wet collections for which agents of deterioration and destruction are not adequately managed or mitigated (less than 66.8% of measures are in place). Colour coding of bars reflects the magnitude of the risk from each agent. Red=catastrophic or extreme, orange=high, blue=medium and green=low. FP=Fluid Preservatives, F=Fire, DLOS=Dissociation - Loss of Specimens, RH=Relative Humidity, WD= Water Damage, PDGO=Pollutants, Dust, Grime, Other, SC=Security and Crime, T=Temperature fluctuations, PF=Physical Forces, DLOSD=Dissociation - Loss of Specimen Data, P=Pests, LU=Light and UV.

For wet collections, the three potentially catastrophic or extreme agents are Fire, Fluid Preservative (levels and concentration) and Temperature fluctuations. Pollutants, Dissociation-loss of data and Dissociation-loss of specimens are considered as high risks.

- **Most (83%) of collections do not have adequate mitigation in place for Fire and for management of Fluid Preservative (86%)** (Fig. 4). The absence of appropriate and functioning fire suppression systems, the presence of flammable materials other than the actual specimens in the collection storeroom, the lack of appropriate specimen containers and lids and regular, documented checks for both preservative level and concentration are the main contributing factors.
- **Almost half of the collections do not have adequate Temperature fluctuation mitigation**. In many institutions climate control infrastructure is absent, or if present it is unreliable or dysfunctional.
- **Dissociation - Loss of Specimens also has a low number of collections (29%) for which the required practices are in place.** Management of this risk requires documented, systematic processes that are implemented for managing new incoming specimens, movement of specimens and loan management. High turnover of staff and the absence of succession planning adds to the risk.
- Pollutants, which in this case is mostly related to the use of plastic containers or lids that leach chemicals into the preservative, are also not adequately mitigated in the wet collections.
- Light / UV exposure and Pests are relatively well managed in most wet collections.

DRY COLLECTIONS:

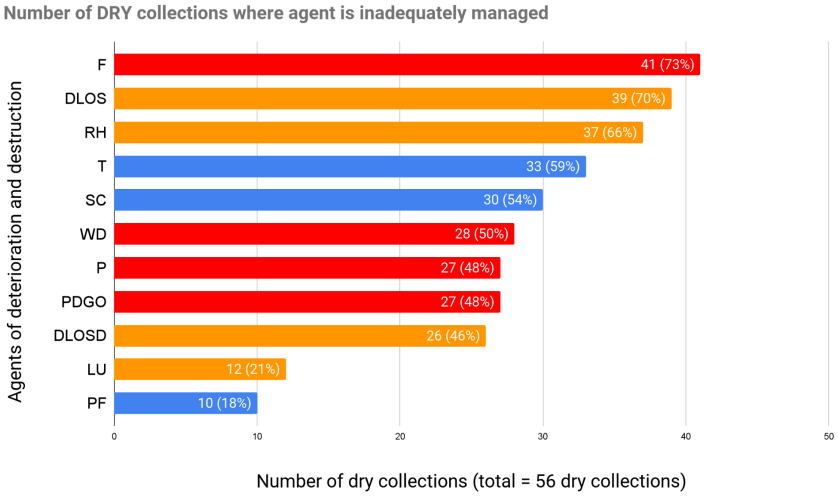


Figure 5. Number and (percentage) of dry collections for which agents of deterioration are not adequately managed or mitigated (less than 66.8% of measures are in place). Colour coding of bars reflects the magnitude of the risk from each agent. Red=catastrophic or extreme, orange=high, blue=medium and green=low.

For dry collections, the four catastrophic or extreme risks are Fire, Water Damage, Pests and Pollutants, which include Dust and Grime as well as chemicals that react with the collection objects, resulting in deterioration and eventual destruction.

- **Fire risk, as for wet collections, is not adequately managed in a large number of collections (73%%) (Fig. 5)** as a result of the absence of an appropriate fire suppression system, as well as the storage of flammable chemicals or other materials with the collection.
- **Pollutants and dust impacts are not adequately managed and mitigated in 48%** of collections and this is mostly through not having appropriate storage materials (archival quality) and not having all specimens suitably protected from dust.
- **The absence of Relative Humidity control mechanisms in 66% of collections** results in chemical reactions with consumables that are in contact with

specimens, and also promotes the growth of mould on specimens which leads to their deterioration.

- **Water Damage** is a risk if specimens are stored directly on the floor, or if there are structural problems with the building that can cause water leaks from rain, or if the collection is stored below ground level or there are water pipes in the collection storeroom. This risk **is not adequately managed in 50% of the collections**.
- Processes to avoid loss of specimens are weak.
- **Pests are well managed in most collections (52%)** but excessive use of pesticides results in other risks including pollutants and staff health. Integrated Pest Management is not practised in the collections.

2.2.3 Understanding the factors influencing or driving the management and mitigation of risks

- The three most at risk collections are under provinces; two in the Eastern Cape and one in the Northern Cape. Resourcing is a major challenge at these institutions, which are severely understaffed and the collections are housed in old buildings (more than 80 years old) that have not had any major upgrades and are not well maintained.
- Those institutions that have the fewest inadequately managed or mitigated risks generally have recently renovated or constructed buildings.
- While the age and maintenance of the building housing the collections is important, so is implementation of standards and practices and this can address or at least reduce the risks. The institutions that have developed policies and workflows for collection care, and actively implement these have a lower number of risks that are not adequately mitigated or managed.

** For a detailed explanation of how risks to the collections were assessed, please refer to Annexure 2: Collection Assessments Analysis Methods*

Table 2. Extent to which the different agents of deterioration and destruction are managed or mitigated in collections across all institutions (values represent the % of mitigation / management measures that are in place). Red=inadequately managed / mitigated (<33.4%); orange = partly managed / mitigated (33.4-66.7%); green = adequately managed / mitigated (>66.7%).

WET COLLECTIONS

	F	RH	FP	DLOS	PDGO	T	SC	DLOSD	WD	PF	P	LU
MEAN	51.0	51.5	54.7	58.0	59.0	62.3	63.3	64.9	65.2	69.9	71.1	87.7
MINIMUM SCORE	16.7	0	24.2	29.2	30.8	0	24	37.6	0	45.6	26.8	0
MAXIMUM SCORE	94.4	100	70	71.4	89.2	100	92	78.2	100	90.4	100	100

DRY COLLECTIONS

	RH	F	DLOS	T	PDGO	SC	DLOSD	P	WD	PF	LU
MEAN	55.6	56.8	58.1	62.3	64.8%	65.7	65.9	67.6	68.3	77.7	79.1
MINIMUM SCORE	21.4	33.3	31.9	9.4	34.7	24	37.6	38.2	0	34.4	50
MAXIMUM SCORE	100%	94.4	72.1	100	82.6	92	87.6	94.4	100	93.8	100

PF=Physical forces; DLOS=Dissociation - loss of specimens; DLOSD=Dissociation - loss of specimen data; RH=Relative humidity; T=Temperature; LU=Light/UV; PDGO=Pollutants, grime, dust; FP=Fluid preservatives; P=Pests; WD=Water damage; F=Fire; SC=Security/crime

2.3 Implementation of recommended standards and practices for curation and collection management

2.3.1 Implementation across all collections

This analysis covers the extent of implementation of the standards and practices recommended in the NSCF Collection Management and Conservation Manual (2021), based on the verified responses to 95 questions in the collection assessment questionnaire.

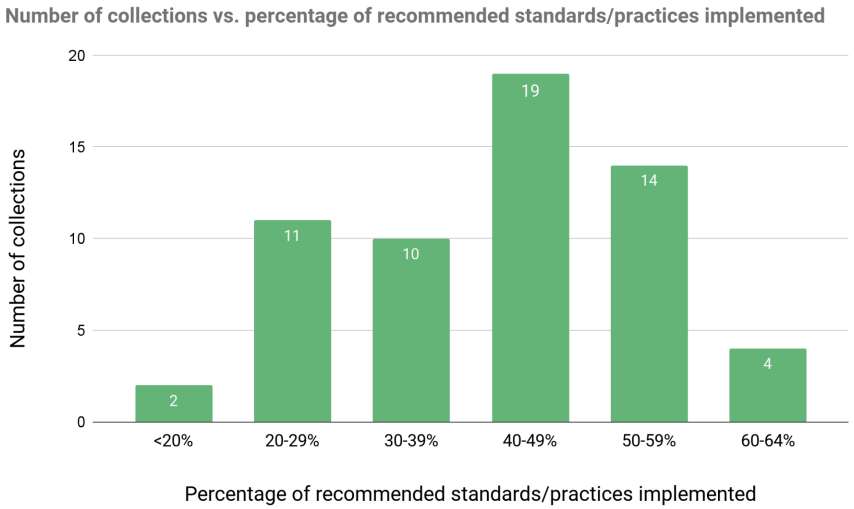


Figure 6. Extent of implementation of the standards and procedures recommended in the NSCF CMC Manual at the level of collections.

The average percentage of practices and standards fully implemented across all collections was 42%. The lowest scoring collection had 5% of practices and standards implemented and the highest scoring collection 65%. The biggest gaps across collections were in scientific curation practices (26% implemented), collection management practices (33% implemented), and storage infrastructure (40% standards met).

The number of collections for which specimen data have been captured either in a spreadsheet or a database has increased substantially since 2010, and more than half of the collections have more than 75% of the specimen data transcribed. Most institutions have some form of backup for the database, but there is only a systematic, full backup process at 37% of institutions (Fig. 7). There is a low level of management of specimen images and in many cases, these are stored on various individuals' desktops or the location of images is uncertain, which will lead to the loss of these resources unless systematic processes are established. Only three institutions actively publish data on the Global Biodiversity Information Facility (GBIF) (Fig. 7).

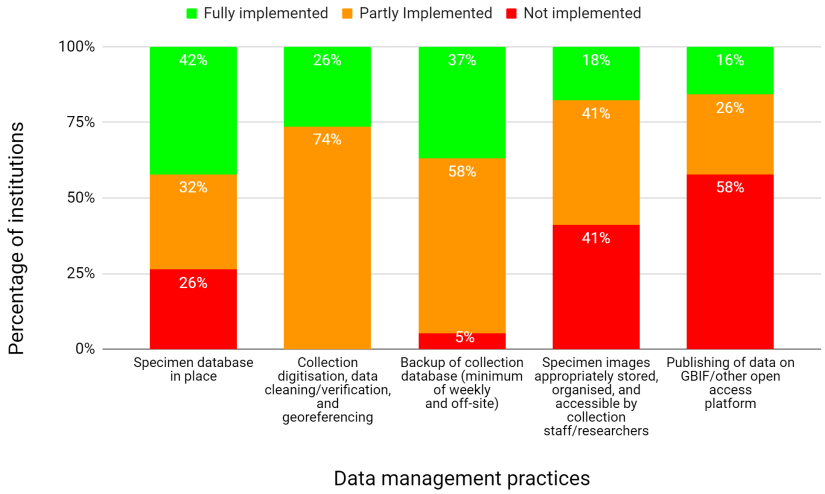


Figure 7. Details of implementation of digitisation practices. The percentages refer to the institutions scoring either fully implemented, partly implemented or not implemented for each practice.

2.3.2 Drivers of Progress

- Eighteen of the 60 collections assessed scored above 50% for recommended standards and procedures fully implemented. In general, these are smaller collections, that have scientifically qualified staff, and / or there is some form of institutional or team support (more than three staff associated with the collection, senior person, manager).
- In the case of six collections scoring above 50%, there was at least one staff member who completed the NSCF Collections Management & Curation Course.
- There are outliers where none of these explanations apply and these may be related to unusually motivated individuals, or the assessment may not be accurate (other collections in the same institution scored exceptionally low which suggests either a significant lack of staff engagement across collections or differences in moderation of the self assessment).

- The low scoring collections, where less than 40% of recommended standards and procedures have been implemented, even partly, include six orphaned or unstaffed collections, and four large collections that were unstaffed or neglected by the responsible staff for many years, and the extent of the work required is likely to be overwhelming for one or two newly appointed staff members.
- Three of the highest scoring institutions for data management practices include two science councils and one national museum . All three of these institutions have at least one member of staff dedicated to data management.

2.4 Professional, scientifically credible practice: Documentation development

2.4.1 Status of institution-level document development

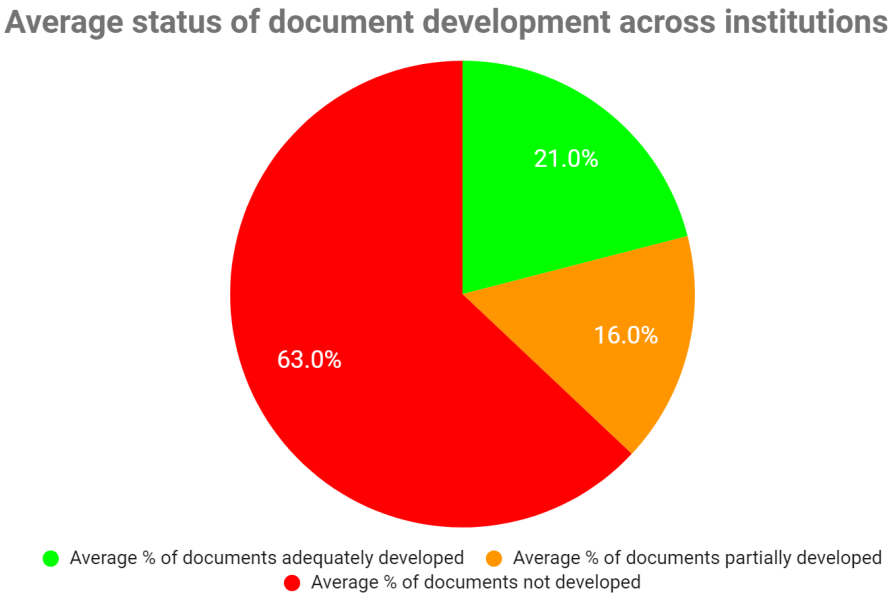


Figure 8. Average percentage of institutional collection-related documents adequately, partially and not developed across all institutions.

Institution-level documentation refers to collection-related documents that are more suitably developed and managed at an institutional level such as policies, registration relevant to the type of collections held, risk and disaster management documents specifically for the collections, guidelines for the ethical behaviour of staff in terms of the collections (e.g. ownership, legal compliance, best practice) as well as health and safety documents.

- The average percentage of recommended documents developed across institutions was 21% (Fig. 8), with the lowest-scoring institution having developed 2% of documents, and the highest-scoring institution having developed 58% of documents.
- The biggest gaps were in the categories of registrations for specific types of collections, building safety, and risk management plans, reports and procedures.

2.4.2 Status of collection-level document development

Collection documentation includes various hard copy registers (e.g. accessions, loans, visitors), background or summary information on the collection, curation plans, as well as standards documents, workflows and risk monitoring reports.

- The average percentage of recommended documents developed across collections was 40% (Fig. 9), with the lowest-scoring collection having developed 3% of documents, and the highest-scoring collection having developed 76% of documents.
- The biggest gaps were in the categories of permit workflows, planning documents, curation standards, document management, collection and data management registers, and collection care workflows.

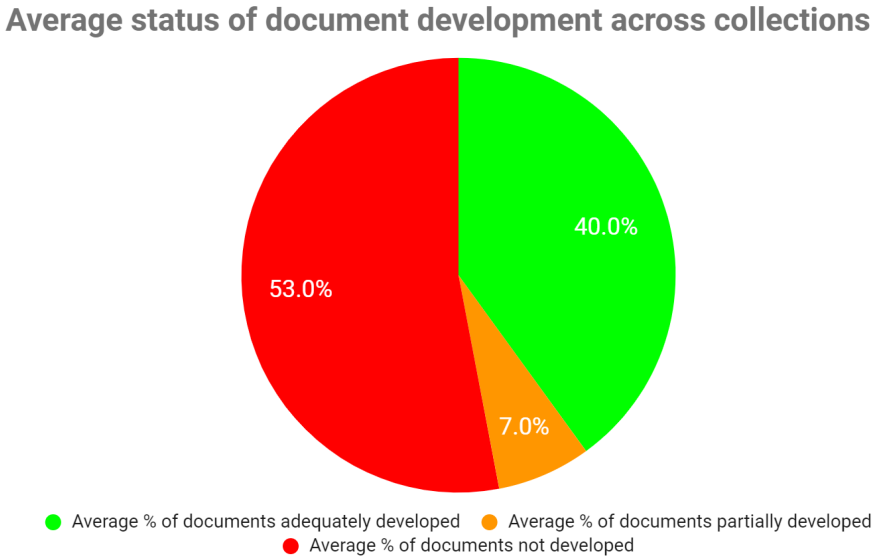


Figure 9. Average percentage of documents adequately, partially and not developed across all collections.

2.4.3 Progress with document development since 2010 assessment and drivers of progress

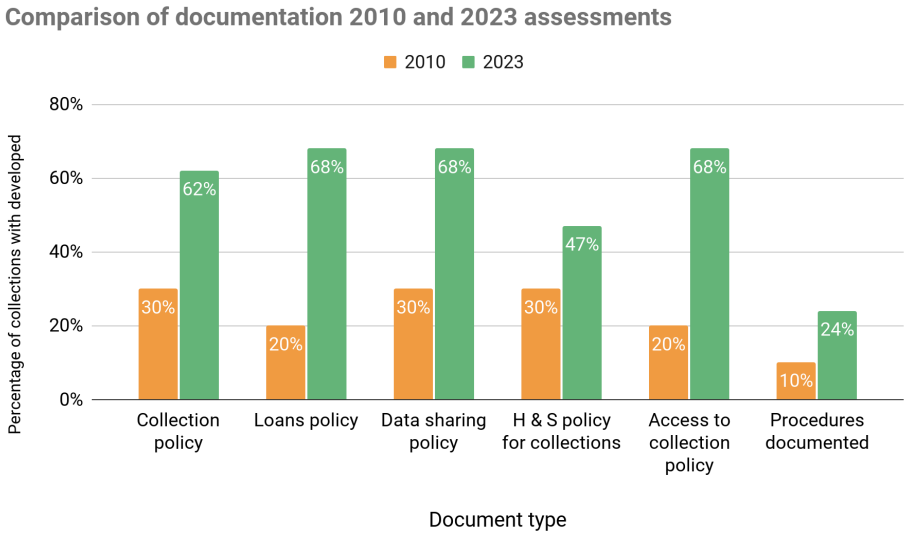


Figure 10. Percentage of collections with adequately developed documents in 2010 compared to 2023.

- There has been a considerable increase in the percentage of documents developed across collections since the 2010 collections assessment (Fig. 10). The percentage of collections that had developed adequate Access and Loans Policies increased by 48% in 2023, compared to 2010. The percentage of collections that developed a Data Sharing Policy increased by 38%, a Collection Policy by 32%, a Health & Safety Policy by 17% and Procedures Documents by 14%

- The most significant motivation for developing documentation is probably related to compliance and audit procedures. Those institutions that have aspects of collection work audited will have had more pressure to develop policies and procedures.
- The highest percentage of documents completed was at the municipal museum, which may have been motivated by audit processes and compliance, but also an extraordinary effort to complete the list of documents

recommended in the NSCF Manual. The number of staff involved in the document development at this institution is small, but there is obviously recognition of the importance of documentation.

- In large institutions such as universities there appears to be a reliance or expectation that structures or units outside the collections take responsibility for various documents including policies, and documents related to risk management, buildings and health and safety.
- The provincial museums have the lowest percentage of documents developed and this may be related to audit processes not focusing on collection-related outputs.

2.5 Staffing status

Table 3. Comparison of the number of staff associated with collections, including only those institutions that were assessed in both 2010 and 2023

Measure	2010	2023	Change
Total number of staff (curators, scientists, collection managers, technicians, assistants)	**183**	**149**	**19% decrease**
Total number of scientists associated with collections (includes curators with research role / expertise)	**77**	**66**	**14% decrease**
Total number of collection managers, technicians and assistants	106	83	22% decrease
Zoological collections - total number of staff	96	66	31% decrease
Herbaria - total number of staff	68	65	4% decrease
Palaeontology collections - total number of staff	28	14	50% decrease
Zoological collections - number of scientists	50	31	38% decrease

Ratio of Staff to Specimens

- The ratio of staff to specimens has significantly increased from 67,502 specimens per staff member in 2010 to 103,702 in the current assessment.
- The highest ratios are in entomology and other invertebrate collections, with some exceeding 500,000 specimens per staff member.

Staff Turnover

- Only 30% of the 2010 staff are still employed in the same institution.
- 30% have retired, and 33% have resigned, with many posts being vacated and filled multiple times between 2010 and 2023.
- High turnover leads to loss of institutional memory, gaps in knowledge transfer, and challenges in maintaining consistent curation and collection management processes.

Changes in Institutional Leadership

- Of the 16 institutions included in both the 2010 and the 2023 assessments, only five have the same senior manager (Director equivalent).
- If the various management levels (Executive and Deputy Director level) are considered, then of the 26 managers who were in place in 2010, only six are still appointed in this role, with some positions having been filled multiple times during the 13-year period.
- This high turnover affects understanding and support for the NSCF's objectives, continuity in planning and strategy, and effective leadership in collection management.

Transformation / Equity

- Staff turnover has increased diversity: Black staff at curator/scientist level rose from 5% to 19%, and women from 30% to 53%.
- At the technician/assistant level, the composition remains around 70% Black and 45% women, showing minimal change since 2010.

3 NSCF impact, future work and recommendations

3.1. NSCF impact

Collection Management and Conservation Manual (2021) & Collection Management Course

A 2011 report on the natural science collections in South Africa highlighted several significant challenges with the collections, including that these were managed in a highly fragmented and largely isolated environment, and that there were no common policies or standards or strategy or approach to research. Through a consultative and collaborative effort, policy guidelines, standards and procedures were developed and the NSCF Collection Management and Conservation Manual was published in 2021 and distributed to all staff in partner institutions. An Access Policy, with decision-making process and procedure for appeals was also developed.

The NSCF Manual formed the basis for the collections assessment process and also serves as an invaluable resource to the natural science community to ensure best practices and procedures are followed in collection and data management.

The Collections Management Course was launched in May 2021. The NSCF Hub developed the content for the course based on the Collections Management & Conservation Manual and co-ordinated webinars and various other virtual forums to provide guidance and support for implementing the Manual.

In collections where staff attended the course, there has been a concerted effort to complete the list of documents recommended in the NSCF Manual. The increase in the number of documents developed since the 2010 assessment may be ascribed to the publishing of the Manual and running of the collections management course.

The number of collections for which specimen data have been captured either in a spreadsheet or a database has increased substantially since 2010, and more than half of the collections have more than 75% of the specimen data transcribed. In 2010, 12 different softwares were used for the specimen databases with Access (mostly flat) being the most commonly used. By 2023 only six different softwares were used, with the most common being Specify and BRAHMS which were both developed internationally for natural science collections, and are recommended in the NSCF Manual.

Collections Assessment

The facilitated self-assessment process is aimed at providing support for the future of natural science collections in South Africa, but also for transformation, building staff capacity, and creating a collaborative learning and vibrant environment that will ensure sustainability.

Follow-up communications with community members reveal that the assessments have spurred action, leading some institutions to make positive changes to meet standards, enhance practices, and reduce risks. The institutions that have developed policies and workflows for collection care, and actively implement these have a lower number of risks that are not adequately mitigated or managed.

The assessment outcomes serve as an accurate baseline for collections to gauge progress and improve their status by working towards addressing the gaps and recommendations contained in their feedback documents.

Investment in collections

The NSCF has assisted with the rescue and relocation of several orphan collections, including infrastructure and staff investments. This included orphaned collections held by institutions that lacked resources to care for them, university collections developed by retiring staff, and private collections held by individuals no longer able to care for them or who were deceased. Without interventions, these collections would have deteriorated and eventually have been lost or they would have been sold or donated to overseas collectors or institutions which limits accessibility by local researchers. Some collections that were considered at risk during the 2010 assessments are now considered secure, in several cases due to storage infrastructure upgrades funded through the NSCF.

3.2 Recommendations and future work

Future work

- The methodology and approach for the collection assessment are novel and could be used internationally by other research collections or network initiatives (there is currently no standard system for assessing management and curation status). This will be published in appropriate international journal/s.
- The assessments have revealed some collections that remain at significant risk of deterioration and loss. There are a number of factors that are responsible for this situation and in some cases the collections or at least the most significant specimens should be moved to more secure institutions. This will require negotiation and support for packing and moving the collections and their accessioning at the receiving institution. Guidelines for decision-making for

moving orphaned collections are required, including resourcing of recipient institutions and legal considerations.

- Support will be provided to institutions for addressing gaps in documentation (policies, procedures, workflows and standards) and for some of the curation processes. This support will be in the form of a number of Communities of Practice, co-ordinated and facilitated by the NSCF Hub together with staff from partner institutions.
- The NSCF has also developed a tracking tool for institutions and collections to use in monitoring their progress towards improving their assessment status.
- Interventions in the form of guidance and support for aligning plans with the gaps identified are planned, with the assistance of organisational development and transformation facilitators.

Recommendations

Several recommendations have been made to institutions to assist them with improving their assessment status and so ensure the long-term security and sustainability of the collections in their care.

In addition, the following recommendations should be considered and implemented by institutions:

The decrease in staffing since 2010 is a concern because collection management and curation are labour intensive and inadequate numbers of appropriately qualified and experienced staff will lead to the deterioration or loss of collections. In addition, without staff who are actively engaging with the research community, the collections are unlikely to grow or be used for research. **Ideally, additional staff should be appointed at institutions that have an excessive ratio of specimens to staff** but considering the current economic climate, and the significant social demands on state funding, this may not be realistic. In such cases, institutions may need to consider **roles and responsibilities of existing staff, and have detailed planning and performance management** to ensure that priority activities are effectively carried out. Institutions where the staffing is so low that collection management and curation are impossible and this situation is unlikely to be addressed in the short term, may need to seriously consider relocation of at least some of the collections to other institutions.

Staff retention is an additional challenge that needs attention. While low salaries and lack of opportunities for career progression may be out of the control of institutions, ensuring supportive, collaborative and positive environments may reduce staff turnover. The NSCF provides opportunities for shared learning and engagement with staff from other institutions, and active participation will benefit both individuals and institutions. Managers need to encourage and enable staff participation in such activities.

There should be a **moratorium placed on collecting new material or accepting donations in those collections that have few of the significant agents of deterioration or destruction adequately managed or mitigated, that have low levels of standards or practices implemented, that have little to no documentation, where there are significant backlogs in unaccessioned material and where there are staff shortages**. Once some progress has been made then the moratorium could be lifted and expansion of the collections resume. This will be a difficult decision for managers to take and to implement but it is necessary to secure existing collections and to not increase the extent of deterioration or loss of collections.

It is essential that there is a **move to online, open access to specimen data sets and images of specimens to increase the pool of researchers, postgraduate students and other stakeholders who use the collections**.

This is in line with global strategy, with many institutions and programmes that are investing large amounts of resources into digitisation as a mechanism to secure and protect but at the same time increase use of the collections. It has become widely recognised that collections that are not used have limited justifiable value, and that given the threats to biodiversity, institutions have an obligation to make data accessible for conservation related research and actions.

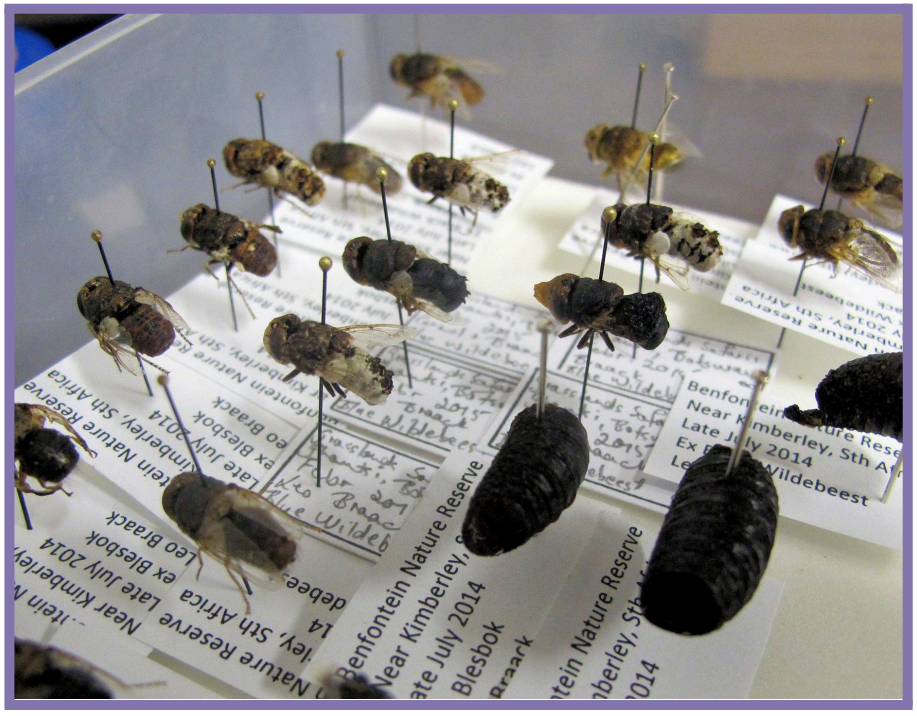
There has been significant progress made in capturing specimen data for most of the collections assessed, but most of the data sets are not readily accessible, and there is a very low number of data sets available on GBIF. Those institutions that do have data on GBIF are able to track and report on global use of their data, increasing the significance of the collection and institution. There are mechanisms available for protecting localities for threatened or sensitive species.

Most institutions do not have systems for **managing images of specimens** and it is probable that a significant number of these have been or will be lost when projects end or hard drives are cleared when staff leave or retire. This should be addressed by institutions or if they do not have the resources for long term storage of images, alternate arrangements must be made.

The NSCF is currently involved in imaging of herbarium specimens and the type specimens in some of the palaeontology and vertebrate collections. The aim is to provide a digital version of specimens which reduces the impact of handling during examination or the risks associated with postage and to make these images accessible in order to increase use of the collections. Similarly, a process has recently been initiated to digitise documents related to the collections, specifically catalogue books and field or research notes of collectors. The digital versions of specimens or documents will never replace the physical version but the former serve to protect and make accessible the latter.

While most institutions support these initiatives, there may be resistance from some individuals and institutions because of a perceived loss of potential revenue from charging for online access, or because of a concern about loss of control of use of images. The potential revenue generated, which is unlikely to be significant, has to be weighed up against the impact of low levels of use.

Digitisation and making data, images and documents accessible online are critical next steps for addressing the challenges confronting natural science collections, and for ensuring that South Africa and its collections are part of the global movement towards digitisation and open access.



Annexure 1: List of collections included in the 2023 collection assessments

Table 1. Institutions included in the 2023 collections assessment: governance structure, main collections, overall size of collections and number of staff associated with the collections (including collection staff and scientists).

Governing Department	Category	Institution	Major collections (score out of 10 for size / uniqueness, score out of 10 for research use) (+ number of minor collections) green=major collections (blue=major collections with high level of use bold=significant collections (historical or strategic importance)	Estimated number of specimens / specimen lots	Number of staff: permanent posts filled (+ contract staff)
Department of Sports, Arts & Culture	National Museums	Ditsong National Museum of Natural History	***Coleoptera (10, ?)** **Lepidoptera (10, 2)** General Entomology (6, 5) ***Herpetology (10, ?)** **Birds (10, 4)** **Mammals (10, 6)** **Archaeozoology (8, 5)** **Karoo Palaeontology (10, 2)** **Plio-Pleistocene Palaeontology (8, 5)**	1,483,982*	17
	National Museums	Iziko South African Museum	**Cenozoic Palaeontology (10, 7)** **Terrestrial Invertebrates / Entomology (10, 7)** **Invertebrate Palaeontology (8, 2)** **Karoo Palaeontology (10, 5)** **Marine Biology (10, 10)** Terrestrial Vertebrates (6, 6)	3,521,063	8 (+9)
	National Museums	KwaZulu-Natal Museum	Entomology (6, 7) Arthropoda (5, 3) **Oligochaeta (9, 5)** **Malacology & Marine Invertebrates (9, 5)** Herpetology (5, 3) Palaeontology (5, 1)	432,200	8
Eastern Cape Department of	Provincial Museums	Albany Museum	Entomology & Arachnology (6, 5), **Freshwater Invertebrates (9, 7),**	623,523	4

Sports, Recreation, Arts & Culture			*Palaeontology (?, ?), **Devonian Lab ((9, 3),** Selmar Schonland Herbarium (6, 7) (+2)		
	Provincial Museums	Amathole Museum	Shortridge Mammal Collection (7, 1)	37,222	1
	Provincial Museums	East London Museum	Birds (6, 3) , Malacology (7, 4) (+1 minor collection)	38,070	2
	Provincial Museums	Port Elizabeth Museum	**Herpetology (8, 5)** **Marine Mammals (9, 6)** **Prey Identification collection (9, 0)**	62,825	5
Northern Cape Department of Sports, Art & Culture	Provincial Museums	McGregor Museum	Mammals (5, 0), Birds (5, 0), Herpetology (5, 0), Archaeozoology (6, 0), Herbarium (5, 4)	72,266	1
eThekwini Municipality	Municipal Museum	Durban Natural Science Museum	Mammals (6, 5), Birds (7, 3), Entomology (5, 5) Palaeontology (5, 0) (+4 minor collections)	245,095	5
Department of Agriculture, Land Reform & Rural Development	Science Councils	Agricultural Research Council - Plant Health & Protection	**National Collection of Insects (7, 8)** **National Collection of Nematodes (10, 5),** **National Collection of Arachnids (10, 6),** **National Collection of Fungi (10, 5)**	1,565,555	11
	Science Councils	Agricultural Research Council - Onderstepoort Veterinary Research	**National Tick Collection (9, 1)** National Collection of Insects of Veterinary Importance (6, 6) **National Collection of Animal Helminths (9, 2)**	39,061	4
Department of Fisheries, Forestry &	Science Councils	South African National Biodiversity Institute	**National Herbarium (10, 10),** **Compton Herbarium (9, 7),** KZN Herbarium (6, 5)	2,207,600	52

Environment					
Department of Science & Innovation	Science Councils	National Research Foundation: South African Institute for Aquatic Biodiversity	**National Fish Collection (10, 10),** (+2 minor collections)	100,000 (includes 1,014,996 individual specimens)	6
National Department of Health	Science Councils	National Institute for Communicable Diseases	**Medical Entomology Collection (9, 1)**	64,000	1 (+1)
Department of Higher Education & Training	Universities	University of the Witwatersrand (Evolutionary Studies Institute)	**Karoo Vertebrates, Cenozoic Collections, Palaeobotany, Fossil Wood, Comparative Faunal Collection, Invertebrate Fossils (10,10)**	259,302	2
	Universities	University of the Witwatersrand	C.E. Moss Herbarium (6, 4)	200,600	3
	Universities	University of Cape Town	**Bolus Herbarium (7, 7)**	412,000	2
	Universities	University of KwaZulu-Natal	Bews Herbarium (6, 5)	201,000	3
	Universities	University of Pretoria	H.G.W.J. Schweickerdt Herbarium (6, 7)	133,100	2
	TOTAL	**17 institutions**	**69 collections**	**11,708,464**	**141 staff**

***not included in the collections assessment process**

Annexure 2: Collection assessment analysis methods (abbreviated)

1. Collection Risk Management and Mitigation Analysis

Natural History Collections are indispensable and irreplaceable data repositories, serving numerous vital societal functions. Regrettably, these collections often suffer due to being underfunded and understaffed. Such constraints can lead to inadequate care and maintenance, posing significant risks to the collection objects and their associated data, which may deteriorate or be destroyed. Given this, it is crucial to have a fundamental understanding of the risk factors that can lead to such deterioration or destruction. This knowledge is essential for implementing mitigating measures and directing appropriate funding.

To assess the perceived risks that could lead to the deterioration or destruction of collections, and to understand the level of controls in place for managing, mitigating, and safeguarding these collections from degradation and disasters, we adopted a structured approach.

The first step was to calculate a **standard magnitude of risk score** for each of the agents of deterioration and destruction for collections, using the approach of the ICCROM/Canadian Conservation Institute's Guide to Risk Management of Cultural Heritage (2016). This methodology takes into account the probability of occurrence for various events (e.g., fire, earthquake, flooding, theft) or the duration of processes (e.g., fading of color, effects of mold or dust, loss of fluid preservative), along with their impact on individual specimens and on the collection as a whole. The scores, ranging from 0 to 15, positively correlate with the severity of the risk. These scores were calculated separately for wet and dry collections, and are standard values that were used for all the collections.

The second step was to evaluate **the extent to which each of the agents of deterioration and destruction for collections is mitigated or managed in the specific collections** assessed. This involved analyzing a set of moderated questionnaire responses provided by each of the 60 individual collections across 18 institutions. From the complete dataset of questionnaire responses, we identified a subset of questions on practices, materials or infrastructure that are related to mitigation or management of the risks associated with the agents of deterioration and destruction. For example, for *Temperature*, questions relating to the presence of functional air conditioners in the collection storeroom were used; for *Fire* we included questions on fire detection and suppression systems, presence of fire doors, whether storage infrastructure is composed of wood or metal, whether there are chemicals or paper or other materials stored with the collection. The response options for each chosen question were assigned a standard numeric score and weighted according to their potential impact on a collection relative to the agent of deterioration or destruction. This process created a scoring dictionary.

Using regular expressions, we matched the questions and their standardized numeric scores from the scoring dictionary to the responses provided by the collections' respondents. This method was used to **calculate control scores out of a possible 15** for each agent of deterioration and destruction for each collection, based on their responses to specific questions related to each agent. The value or contribution to the score of 15 for each question varied, depending on the number of questions associated with each agent of deterioration and destruction (i.e. if there were a few questions associated with an agent the value would be higher for each question and if there were many questions their value would be lower), and depending on how significant the particular infrastructure or practice are in terms of the risk (agent). For example, for *Fire*, a functional fire suppression system in the collection storeroom has more impact on mitigating the impact of fire on a collection than having fire doors and it was weighted accordingly. Our approach also took into account the differential impacts that these agents can have, depending on the preservation method used for each collection. Consequently, the analysis was conducted separately for fluid-preserved (wet) collections and dry collections (e.g., skins, skeletal elements, pinned insects, slides, and fossils). There were 12 agents considered for fluid-preserved collections and 11 for dry collections. The scores for each agent were scaled and standardized to a range of 0 to -15. A score of 0 indicates the absence of any mitigation measures or controls, while a score of -15 indicates comprehensive measures and controls are in place to mitigate against perceived risks of deterioration and disaster. In our analysis, we handled NAs and missing values to normalize the scores and avoid biasing the results.

To graphically represent the severity of the different risks (agents of deterioration and destruction) and the extent to which these are mitigated or managed for individual collections, we plotted the standard magnitude of risk values (y-axis) against the level of risk mitigation (x-axis). This was done using a quasi-heatmap with a 3x3 matrix. The **risk magnitude scores were depicted by different coloured points**, categorized into four groups based on their potential impact on collections:

1. **Low Risk (green), with scores under 7.5 out of 15**, signifies events that are very infrequent (every 300 years or more) or slow deterioration processes (over 300 years), likely causing minimal losses (less than 1%) to individual specimens and the collection.
2. **Medium Risk (blue), with scores between 7.5 and 9.499**, indicates events that are infrequent (about every 100 years) or deterioration occurring within this timeframe, potentially leading to a loss of 1 to 3% of individual specimens and the collection. The risk magnitude remains medium, and continuous mitigation is necessary.
3. **High Risk (orange), with scores between 9.5 and 11.499**, represents events that occur relatively frequently (every 30 to 100 years) or deterioration within this period, likely causing a loss of 3 to 10% of the value of individual specimens and the collection. The risk magnitude remains high, necessitating ongoing mitigation measures.
4. **Extreme or Catastrophic Risk (red), with scores between 11.5 and 15**, reflects frequent events (every 1 to 10 years) or rapid deterioration, with potential losses ranging from 10 to 100% of the value of individual specimens and the collection.

For the NSCF collections assessment, the value of the risk magnitude on the y-axis is consistent across all collections of the same type, tailored specifically to the South African context. The quasi-heatmap illustrates the interplay between risk magnitude and mitigation measures, consisting of 9 cells in 4 unique colors. Blue cells indicate no immediate action is needed. Green cells denote non-urgent situations requiring ongoing attention and maintenance of mitigation measures. Yellow cells represent less urgent scenarios that still require attention and maintenance of mitigation measures. Orange and Red cells, however, indicate risks that require urgent mitigation and management.

Finally, we generated checklists for each collection, containing individual risk factors. These were based on responses to questions associated with specific risk agents. The questions were grouped according to agents of deterioration and destruction, with scores calculated from the responses provided by respondents. The score each question received was used to assign an individual risk factor status. Based on these questions, individual risk factors were categorized into three groups. Each group represented actions or mitigation measures required for each agent and was indicated by differently coloured cells in the checklist. Green cells indicate that the necessary actions or mitigation measures are in place. Orange cells signify that actions or mitigation measures are partly in place. Red cells denote that the necessary actions or mitigation measures are not in place.

Data pre-processing, manipulation, and visualization were done in R v.4.3.0. (R Development Core Team 2023). For data pre-processing and manipulation, the R packages dplyr v.1.1.4 (Wickham et al., 2023), readr v.2.1.4 (Wickham & Hester, 2023), reshape2 v.1.4.3 (Wickham, 2007), stringr v.1.5.1 (Wickham, 2023), and tidyr v.1.3.0 (Wickham, 2023) were used. For visualizations we used the R packages ggplot2 v.3.4.4 (Wickham, 2016), ggrepel v.0.9.4 (Wickham, 2023), and extrafont v.0.19 (Wickham, 2023).

2. Implementation Status of Collection Management and Care Practices and Procedures Analysis

Understanding the degree to which a set of standard recommended practices and procedures are implemented is vital for natural history museums in managing their collections. This ensures the preservation, conservation, and accurate presentation of collection objects and their associated data. Moreover, it provides a baseline for tracking an institution's progress in implementing standard recommended practices and procedures, and in prioritizing the execution and normalization of standard recommended practices. By adhering to a set of recommended standards, museums not only safeguard their collections from physical and environmental damage but also uphold scientific and educational integrity. This enables museums to serve as reliable repositories of natural science, providing invaluable resources for research, education, decision-making and public engagement. Considering this, we assessed the current level and extent of implementation of the practices and procedures recommended in the NSCF Collection Management and Conservation Manual (2021).

We identified and extracted a subset of 95 questions from the collection assessment questionnaire using regular expressions. The purpose was to evaluate the progress collections have made over the past two years following the release of a manual for implementing recommended standards and procedures, and to identify friction points in the implementation process. The selected questions were divided into seven categories deemed relevant to natural science collections. These categories included Storeroom Structure and Infrastructure, Collection Space and Organisation, Collection Management Practices, Storage Infrastructure, Scientific Curation Practices, Specimen Data/Image Management Practices, and Risk Monitoring and Response.

For each question, we developed a scoring dictionary, assigning a standard numeric value between 0 and 1 based on the respondent's answer. We then matched these scores with the corresponding questions and responses of the respondent using regular expressions. Responses indicating no implementation or uncertainty about implementation received a score of 0 (Not Implemented), while those indicating the implementation of a practice or procedure received a score of 1 (Implemented). Scores between 0 and 1 were classified as Partly Implemented. In our analysis, we carefully handled NAs and missing values to normalize the scores and mitigate any bias in the results by excluding the question or component from

the analysis. Subsequently, we calculated percentage values for each of the seven areas of collection implementation based on the count of each of the three implementation states (Implemented, Partly Implemented, Not Implemented). We visualized these results using a stacked bar chart, with the x-axis representing the seven implementation categories and the y-axis indicating the overall percentage of implementation across the three states.

Furthermore, we developed checklists for each collection. These checklists comprised the broad implementation categories, their associated scored questions, and the implementation state for each question, calculated based on the response to a specific question. The score assigned to each question determined the individual implementation status. We categorized individual risk factors into three groups, represented by differently colored cells in the checklist: green cells for implemented aspects, orange cells for partly implemented aspects, and red cells for non-implemented aspects within each implementation category.

Data pre-processing, manipulation, and visualization were done in R v.4.3.0. (R Development Core Team 2023). For data pre-processing and manipulation, the R packages dplyr v.1.1.4 (Wickham et al., 2023), readr v.2.1.4 (Wickham & Hester, 2023), stringr v.1.5.1 (Wickham, 2023), and tidyr v.1.3.0 (Wickham, 2023) were used. For visualizations we used the R packages ggplot2 v.3.4.4 (Wickham, 2016), ggthemes v.5.0.0 (Wickham, 2023), and extrafont v.0.19 (Wickham, 2023).

3. Documentation Analysis

- Only documents uploaded to the NSCF Google Drive by the deadline were assessed.
- Hardcopy documents were assessed onsite where it was not possible to upload electronic versions.
- The quality of the documents was not assessed, but rather if the documents covered the required content as per the NSCF CMC Manual.
- Documents were categorised according to themes and according to institutional-level or collection-level content.
- Documents were scored according to the following criteria:
    - ➔ n/a - documents not applicable to the specific institution/collection
    - ➔ Score of 0 - no document developed/submitted
    - ➔ Score of 1 - Poor, document does not include basic steps/content required, steps/content unclear; content not directly relevant to the requirements
    - ➔ Score of 2 - Acceptable, document includes basic steps/content required, steps/content is clear
- An overall score was calculated based on the above scoring to depict the **overall implementation percentage** of required documentation (see *'summary value for documentation'* in the reports).
- Pie charts were generated for institutional-level documents and collection-level documents to depict the **overall percentage of documents** that were adequately developed, required further development or had not been developed.
- Graphs were generated for institutional-level documents and collection-level documents to depict the number of documents **per document category/theme** that were adequately developed, required further development or had not been developed.
- A checklist was generated indicating which **specific documents** or content were adequately developed, required further development or had not been developed/submitted. The checklist serves as a guide to institution and collection staff to identify specific documents that require development.

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