Title

Can a Data Repository Survive a Crisis? Development of the Repository Crisis Scorecards

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Abstract

Disaster scenarios are not usually considered by scientists when publishing or archiving data. The goal is often to satisfy more immediate needs and requirements of funders, journal publishers, or collaborators. Yet, recent events around the globe, combined with the increased need for high-quality data to solve large-scale problems, have highlighted the vulnerability of data stored in repositories to crises. To address these concerns, we held a one-month sprint in March 2025 to develop the Repository Crisis Scorecards (RCS) with the goal of helping data repository personnel better assess and understand how their systems and infrastructure might be suited to withstand four crisis scenarios. We adapted the scorecard style proven successful by the EarthCube Research Coordination Network (RCN) on ‘What About Model Data?” because it was approachable, could be adapted to each repository, and could be shared widely without technical tools. We anticipate that the RCS could be used by established repositories, informal data collectors, and anyone holding data to plan for more sustainable and robust long-term data publication and preservation. Here, we outline the process for developing the RCS, share lessons learned, and next steps for its ongoing development.

Keywords

data repository; preservation; disaster; crisis; resilience; risk preparedness

Introduction

Societal change and natural and human-caused disasters (e.g., fires and floods) can lead to the loss of data and information from repositories, museums, and archives (e.g., Aguera, 2025; Kirkwood *et al.*, 2023; Merrill, 1943; Thorsheim, 2013; Tyler, Fucsko and Roberts, 2023). Published literature and rescue efforts (e.g., Hsu *et al.*, 2015; Latapy *et al.*, 2023; Walker *et al.*, 2018) usually focus on saving, downloading, or scraping individual datasets (e.g., Data Rescue Project) or on making data accessible in emergencies (e.g., Zhang *et al.*, 2024). While these activities have value, less attention has been paid to identifying the risks to the repositories themselves and the ability to continue the core mission of preserving information and knowledge past the lifetime of an organization charged with its safekeeping. Engaging in preventative planning and measures, beginning with assessment, could improve reactive data rescue efforts or negate their need entirely.

In early 2025, it became starkly apparent that the scientific community and society overall risked losing not just datasets or publications but entire repositories and archives due to political changes in the United States (Dzombak, 2025; McKenzie, 2025; Santarsiero, 2025). This was especially true in the earth sciences, where sudden changes to the data landscape, such as changes in personnel, funding, and infrastructure, heightened these risks (e.g., the Socioeconomic Data and Applications Center (SEDAC); de Sherbinin, 2026). While these crises provided a catalyst for the development of this tool, crises that have posed significant threats to research activities take many forms and require significant planning to mitigate the scientific data loss and maintain stewardship of critical resources across scientific communities.

Repositories have some tools to plan for the risk and impacts of crises on data (DataOne, 2019), including certification frameworks (e.g., Core TrustSeal Standards and Certification Board, 2022; ISO 16363, 2025) that provide benchmarks for data stewardship (Castle *et al.*, 2026; Mayernik *et al.*, 2020). In addition, general disaster planning resources from professional organizations such as the American Library Association (ALA, 2025) and the American Society for Information Science and Technology (ASIST, 2026) as well as a broader body of literature on this topic (e.g., Barateiro *et al.*, 2010; Frank and Yakel, 2013; Gracy and Kahn, 2012; Strecker *et al.*, 2023) provide guidance for repository staff and managers. However, there are significant barriers to accessing and implementing these resources and operationalising them (e.g., Kohn, 2023), as these tools and assessments often require large, complex planning processes and certifications that require significant staff time and money to implement.

While there are ongoing and parallel efforts to mitigate these concerns (e.g., the National Digital Stewardship Alliance (NDSA) levels of digital preservation, NDSA, 2026), the authors saw a need for a rapid assessment tool for repository resilience and so designed and implemented the Repository Crisis Scorecards (RCS). Inspired by the stress tests imposed on US banks to insure their survival by the Federal Reserve in the wake of the 2008 financial crisis (Federal Reserve Board, 2022) and the subsequent Frank-Dodd Act (Federal Reserve Board, 2025), the RCS proposes metrics under four different scenarios for archives and repositories to score themselves on how well they are currently equipped to respond, and determine what changes they may need to make to increase resiliency. The RCS provides a tool for rapid repository assessment both before and during times of crises that takes very little time and offers actionable ways to improve repository resiliency.

Development of the RCS tool

Motivated by the increasing frequency and severity of threats to data repositories, the lead author of this paper initiated development of a tool that would aid repositories in assessing their readiness to respond to crises occurring on varying time scales by drawing on over 10 years of experience with data repositories and certification activities such as Core TrustSeal (Core TrustSeal Standards and Certification Board, 2022). As Chair of the Earth Science Information Partners (ESIP) Sustainable Data Management Cluster (SDMC), he brought this idea forward to the working group for further ideation and development. SDMC began focusing on the topic of repository resilience and crisis mitigation in their regular monthly meetings in early 2025. It was quickly decided that developing the RCS required a faster cadence, so the authors met weekly for the months of February and March 2025 to develop the scorecards and released the first version on April 3, 2025 (Gum and SDMC, 2025). This rapid timeline was motivated by the immediate threats to data and repositories, as well as the need among data professionals for a rapid assessment tool.

The initial development of the RCS focused on 1) developing themes, and 2) developing crisis scenarios, with the inspiration for the scorecard structure being drawn from the EarthCube Research Coordination Network (RCN) on ‘What About Model Data? (Schuster *et al.*, 2023). The seven scorecard themes (Single Repository Dataset Replication, Repository Infrastructure, Routine Operations, Software, Cybersecurity and Access Control, Sustainability, Network) were developed based on the experience of the authors and focused on the areas where the impacts of crises could be actionably addressed. Within each theme, the authors determined the Descriptors and Descriptor definitions, and assigned scores to each of three classes (1-3). Themes that pertained more to datasets themselves and to the impact of data loss were placed in the Data Impact and Recovery Scorecard, while the themes pertaining to repositories were retained in the RCS.

The four scorecard scenarios (1: Natural disaster hits in less than 48 hours, 2: Repository defunding by parent organization or primary funder, 3: Current cyberattack, cybercrime, or other loss of control over cyberinfrastructure, 4: Loss of technical expertise critical to running the repository) were initially developed based on the experience of the authors who staff and/or publish in data repositories, as well as the immediate threats to repositories and their parent organizations that authors saw or experienced. Weights of scenario scores assume that the organization hosting the repository is currently affected by the crisis scenario, and differ based on the magnitude of risk to a particular theme from a given scenario. Version 1.0 of the RCS was published with these four scenarios and the described weights on 3 April 2025 (Gum and SDMC, 2025). These scenarios are generalized, and more detailed examples can be developed with different weights. The scenarios are intended as a starting point for thinking about an organizational response to different crises. Subsequent community feedback illuminated scenarios that were not crises, but that might also threaten repositories (e.g., loss of electricity), and we plan to address these in future versions of the RCS.

Just after the release of the first version of the RCS on April 3, 2025 (Gum and SDMC, 2025), the co-authors leveraged the ESIP community to get initial feedback and input to make improvements, and published version 1.02 on April 15 2025 (Gum *et al.*, 2025a). In addition, communication about the RCS was circulated in the ESIP community, and sharing of the tool was encouraged through brief presentations and conversations with many other ESIP working groups. This network of repository and information professionals at ESIP continued to spread the word about the RCS for piloting and feedback, and downloads from Zenodo increased rapidly during the next few months (1,045 from Versions 1.01 and 1.02, 2025). Further refinements led to the publication of version 1.03 on 5 February 2026 (Gum *et al.*, 2026).

Other organizations of data management and repository professionals (e.g., the American Geophysical Union, World Data System, Research Data Alliance, Council of Data Facilities, European Geosciences Union) also helped raise awareness of the RCS, and awareness and uptake spread quickly both in the US and internationally. By August 2025, the number of downloads from Zenodo (approximately 2,000) indicated that this tool was filling a need in the community.

RCS tool description

1. Resilience Themes

Reflecting on the risk factors previously proposed by Mayernick *et al.* (2020) for scientific data, further thought was given to what categories should be part of the assessment when considering risks to repositories. In the initial stages, there were seven themes, representing a variety of pathways by which a repository might be exposed to risk or mitigate crisis conditions, each with multiple, intersecting facets: physical infrastructure, data/metadata, software, cybersecurity and access control, sustainability, impact, and network. These themes were conceptually reorganized and structured into a rubric framework modeled after the one developed by Schuster *et al.* (2023) for preserving model data. This rubric, the Repository Crisis Scorecards, version 1.03 (Gum *et al.*, 2026), consisted of a pre-work questionnaire and two separate scorecards, one pertaining to repositories and the other to the datasets themselves, including the following themes:

1.1 Repository Resiliency Scorecard (RRS):

- **Single repository dataset replication:** Focusing on the discrete logical copies of each dataset that the repository holds in terms of number, storage media, locations, e.g., offline, intra-national, and extra-national
- **Repository infrastructure:** Centering the various aspects of infrastructure such as such as staff proficiency and having sufficient staff, the possible speeds of data transfer (virtual and physical) for the volume of materials held, and facility features such as reliability of plumbing and continuity of electrical power, which could affect machines, HVAC, and similar
- **Routine operations:** Reviewing regular operations to support resiliency, such as frequency of backups, user-level service agreements, and continuous staff development
- **Software:** Considering a variety of aspects of software as necessary for accessing data and maintaining the repository and its holdings, from the software's criticality for data access and understanding, to how it is developed, documented, maintained, packaged, and built for extensibility, to its licensing and related accessibility outside of the repository of concern, to ease of installation and use in other settings
- **Cybersecurity and access control:** Spotlighting traditional elements of cybersecurity including logging and auditing; change tracking and management; aligned practices for access control, permissions, and privileges; and sufficient staff with appropriate expertise to create and implement policies and other cybersecurity activities
- **Sustainability:** Attending to sunset and continuity plans, diversity of funding sources, maintenance and strategic modernization of the repository infrastructure, codebase, and related items
- **Network:** Engaging with the concept that the repository exists within a community network and querying the nature of its partnerships (both intra and international), how it connects with the public and the public's awareness of the repository's well-being, and what is in place to ease assistance, should assistance be necessary

1.2 Data Impact and Recovery Scorecard (DIRS):

- **Data and metadata:** Concentrating on individual packages and their particular affordances necessary for understanding, reuse, and appropriate maintenance such as data documentation, persistent identifier(s) (PIDs), metadata completeness, alignment with the FAIR (Wilkinson *et al.,* 2016) and CARE (Carroll *et al.*, 2020) principles, and policies for ongoing management, up to and including removal.
- **Impact:** Taking into account the importance of the repository and its holdings to the effectiveness of third-party applications using its data or other materials, to accurate and timely public information for safety and other purposes, to related data systems for completeness and their operations, and in service to other repositories, whether in providing reciprocal holdings and backups or mutual support and expertise.

2. Crisis Scenarios

Several events occurring in the years leading up to and during the development of the RCS helped shape its focus, particularly the Crisis Scenarios. Across the globe, research data repositories and the institutions that support them have faced a range of disruptions, including changes in funding and institutional priorities, natural disasters, geopolitical conflict, infrastructure failures, and workforce instability. Examples include the Hurricane Helene-related data outage (e.g., National Centers for Environmental Information (NCEI; Alder, 2024); the 2025 California fires (Plain, 2025); the loss of funding for NASA's Socioeconomic Data and Applications Center (SEDAC; de Sherbinin, 2026), and disruptions associated with conflict in Ukraine (Marushchak, 2022; Shevchuk *et al.*, 2024) and Afghanistan (Lin, 2025; Ministry of Mines and Petroleum, 2024). Together, these events underscored that threats to data access and stewardship can arise from many sources and affect repositories and research communities across geographic, institutional, and political contexts. These real-world examples informed the development of four crisis scenarios to help repository managers assess their current preparedness and determine future actions to improve resilience. Each scenario is briefly described below.

2.1 Natural Disaster hits within 48 hours

Scenario: A natural disaster, such as a hurricane or wildfire, is forecast to hit the repository's primary facility in 48 hours. The facility's area is projected to suffer heavy devastation, an evacuation order by officials, and loss of local utilities. **The focus is on local destruction of the facility, including all physical devices and their deposits, with an uncertain timeline for facility restoration.**

This scenario tests whether your data is stored in locations that would survive the loss of your primary site, whether your team can operate remotely, and whether you have plans and procedures in place to respond quickly. The emphasis is on physical resilience, geographic distribution of data, and rapid response capability.

Rationale: Natural disasters have historically caused significant damage to repositories during wildfires (e.g., Canberra (Aguera, 2025); South Africa (Kirkwood *et al.*, 2023); California (Plain, 2025)), hurricanes/storms/cyclones (e.g., Hurricane Helene and Asheville (e.g., NCEI (Alder, 2024; NOAA, 2024; 2025)), tsunamis (e.g., Hussain, 2025) and earthquakes (e.g., Hussain, 2025; Podany, 2020). Some argue this scenario is becoming more common due to the frequency and intensity of wildfires, hurricanes, and floods increasing either in response to climate change (e.g., Gazzola *et al.*, 2023; Thomas *et al.*, 2014) and/or due to urban expansion, which has placed repositories in more vulnerable areas (e.g., sea level rise, greater wildfire exposure). The facility could also be destroyed in war by missiles or drones. Total or near-total physical destruction of the facility during war (e.g., Catanzaro, 2026; Lin, 2025; Merrill, 1943) can have results similar to those of a natural disaster.

In this scenario, there may be no warning; in other cases, warnings indicate that the facility site itself is likely to suffer severe damage, which may provide time to take emergency actions to preserve data. However, officials may issue an immediate evacuation order, stopping any work. Another consideration is that key feeds for time-series data (e.g., sensor networks, satellites) may be discontinued (e.g., McKenzie, 2026; Plain, 2025; Putal *et al.*, 2016). In addition to the partial or complete loss of digital assets, damage from natural disasters can also include the loss of local utilities (particularly power) and physical access to the site. The restoration of the facility may depend on external factors unrelated to the facility itself, such as the site being unusable due to changes in local building codes and/or deemed unsuitable for rebuilding.

2.2. Repository defunded by parent organization or primary funder

Scenario: The repository is notified that it is being defunded and is being shut down in one month, with that one month to implement any plans. **The focus of the scenario is on the eventual total loss of the repository, including staff, hardware, and software, but there is some time for mitigating actions to be taken.**

This scenario tests whether the data within the repository can be moved to another host site. A larger organization may still exist and could take some or all of the deposits. Other similar national/international repositories may or may not face the same existential threat, but could accept some deposits. In some cases, data sets may be moved to new sites run by non-profits, citizen scientists and volunteers, e.g., Climate.us (climate.us, n.d.; Yoder, 2026)

Rationale: Historically, many repositories have been funded through short-term contracts that were not renewed, and repositories have had reasonable amounts of time to plan for alternatives. More recently, sudden repository and/or data defunding by the parent organization or primary funder is becoming more commonplace. Examples of this include the threats to funding for the National Center for Atmospheric Research (NCAR) (NSF, 2025; Witze, 2026), the proposed defunding of the Oceans Observatories Initiative (OOI, 2026) which was then reversed (NSF, 2026), and the unforeseen policy changes from national governments, to institutions, to academic departments, e.g., de Sherbinin, 2026).

In some cases, a database may be closed down by an organization as it is regarded as no longer relevant to their mission (e.g., NOAA’s “Billion Dollar Disasters Database; Wholf, 2025), or defunding can specifically target staff needed to run the repository (e.g., Kozlov, Tollefson and Garisto, 2026).

2.3 Current cyberattack, cybercrime, or other loss of control over cyberinfrastructure

Scenario: The facility has been infiltrated, and hostile agents have control of cyberinfrastructure. All access to the cyberinfrastructure has been cut off. This could be a virtual attack for ransom (cybercrime) or strategic advantage in a physical conflict, or a physical attack where hostile agents are physically present in the facility and accessing computers or pulling cables. **The focus of the scenario is on sudden denial of access to any and all deposits without warning, but not necessarily deletion of deposits and systems.**

This scenario tests whether the repository can detect a hostile breach (online or in-person), limit the damage, recover access to clean copies of the data, and restore operations. The focus is on data integrity, access controls, offline resilience, and recovery capability.

Rationale: External cyberattacks from hostile entities, a concern since the advent of the Internet, can range from amateur hackers through to criminals and foreign states, and can be major (e.g., Hatchimonji, 2024; Uhlmann, 2015). Foreign actors may not destroy the data, but may illegally copy the data for commercial and/or strategic purposes (e.g., attack on climate data centers (Houghton *et al.*, 2025; Xu, 2026).

More recently, there is a growing number of automated AI bots crawling repositories, gathering data and indexing information for search engines, AI and large language models, and other purposes. While some bots are rather innocuous, others are sufficiently aggressive that they are increasingly causing service disruptions in repositories and other scholarly communications infrastructures (e.g., Shearer and Walk, 2025).

2.4 Loss of technical expertise critical to running the repository

Scenario: Technical expertise critical to running the repository, such as knowing how to operate, maintain, and extend the software systems, is no longer available. This may be due to the firing or retirement of staff, the sudden massive increase in prices by a commercial vendor, or an open source community or maintainer going away. **The focus is on knowledge documentation, staff cross-training, and software accessibility.**

This scenario tests whether the repository could continue operating if key people were no longer there and/or access to mission-critical software was denied, despite sufficient funding to continue running the repository. It also tests whether the knowledge required to run a repository is in persistent documentation and systems, or exists only in the minds of specific individuals.

Rationale: Technical and institutional know-how are critical to running repositories, especially if infrastructure and systems are legacy or bespoke. Sudden loss of staff (e.g., firing, forced/unforced retirement) who have this knowledge, and understand the history of hardware and software systems and analysis methods, can cripple a repository or result in the disappearance of a dataset or data product (Wholf, 2025). Even if new staff can be hired, a lack of documentation can prevent new staff from understanding or using legacy systems. Software and hardware vulnerabilities can also put repositories at risk, and have even led some repositories to shut down (Strecker *et al.,* 2023).

Findings and Discussion

What We Learned

The RCS was uploaded to Zenodo in April 2025 (Gum *et al.*, 2025a). Between then and March 2026, the RCS had been downloaded over 1,500 times. Following the original publication, we received feedback from colleagues who reviewed or spent time completing the scorecard. Below, we highlight lessons learned from these conversations and next steps for moving this work forward.

There are concerns associated with quantifying resilience. Of those who downloaded the RCS, only a few submitted their responses for analysis using the online form. Personal communications indicated that there may be some hesitation in sharing responses due to concerns over advertising common weaknesses that could be used to identify repositories that should no longer be funded or maintained (Cornwall, 2025).

To address these concerns, a data policy could be developed that would address how collected data are handled (e.g., confidentially, responsibly, ethically). No identifying information about repositories or individuals would be released without explicit consent. This approach might ensure that participants feel secure in providing honest and meaningful feedback.

Who responds can impact the score. Two individuals who support the same repository, a Lead Data Manager and a Lead Technical Developer and Cybersecurity Officer, took the RCS and got different scores: a score of 107 indicating high resiliency and a score of 78 indicating moderate resiliency. This seems appropriate as questions might be answered differently depending on any individual's knowledge of the system's current status as well as different priorities, opinions, and standards for compliance based on perspective and role. A potential solution to resolving such discrepancies is to have repository staff complete the RCS together. That would allow individuals to discuss responses and come to a consensus, making the score more accurate and useful for the entire team. Outside of what the score ends up being, or even whether or not a consensus is reached on what it should be, the RCS provides a platform for understanding these perspectives and considerations that might not be shared otherwise. Therefore, the RCS questionnaire may serve best as an internal assessment tool, with substantial value in prompting discussion and increasing awareness, even if the score is not shared outside the repository.

The RCS can be used as a tool to understand the larger context of data sustainability and preservation. The work of the SDMC resulted in four major Earth Science Research

Infrastructures from Australia (AuScope), United States (EarthScope), Europe (European Plate Observing System (EPOS) and New Zealand (Earth Science New Zealand) starting discussions on how they could together provide international support. Cases where this support might be critical are in times of crises affecting one national system, or the potential impacts of losing access to a particular dataset on the global supply chain (Gum *et al.*, 2025b). While there is evidence of data repository closures, there are few well-documented examples to draw upon (Strecker *et al.*, 2023); a targeted collection of these narratives and corresponding metadata in registries like re3data (GFZ, 2013) would be desirable to better understand how crisis scenarios unfold, lessons learned, and ultimate outcomes. Understanding the resiliency of data repositories allows data holders to better support at-risk data repositories and assist in maintaining scientific knowledge and data for the benefit of communities in the future.

Conclusion

The Ongoing Evolution of the RCS

To further explore the usefulness of the tool, the SDMC sought funding from the Alfred P. Sloan Foundation to provide paid developer time to support further development and refinement of the RCS. An award was made in October 2025 to support collection of additional RCS submissions and to gather feedback on the utility and potential improvements to the tool for it to be applicable across a range of contexts. This project ended in May 2026, with 44 RCS submissions and feedback from those submissions resulting in an RCS version 2.0 (Sutton-Kennedy *et. al.*, 2026). The hope is that continued submissions will support respondents seeking ways to improve existing systems and allow us to better understand the broader landscape of repository resilience. In addition, with ongoing feedback from the community, we hope the tool will continue to evolve based on user needs with the potential release of later versions.

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Competing Interests

The authors have no competing interests to declare.

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