Acta Globalis Humanitatis et Linguarum
ISSN: 3030-1718
Vol. 3, No. 1 (2026): Ver

Collection Management in Museums: Conservation, Risk Management, and Climate Control Protocols

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https://doi.org/10.69760/aghel.026001007

Keywords

collection management
preventive conservation
museum climate control
risk management

Abstract

Collection management is increasingly defined by an operational triad: conservation decision-making, structured risk management, and evidence-based climate control. This analytical review synthesizes current standards and institutional guidance on preventive conservation and collection care, focusing on (a) climate parameters and monitoring protocols, (b) risk assessment and emergency preparedness, and (c) sustainability and ethics in stewardship. A narrative, criteria-driven synthesis was conducted across international standards (e.g., EN/ISO), professional handbooks used in museum engineering practice, and authoritative institutional guidance from museum and heritage bodies. Findings highlight that effective collection management depends less on universal "ideal" setpoints and more on (1) collection-specific vulnerability and acclimatization histories, (2) reliability and interpretability of monitoring data, and (3) integrated governance that connects facilities management with registration, conservation, security, and public access. The study proposes two practical tools for implementation: a comparative climate-control parameter table by material class and a role-based risk management matrix. Recommendations emphasize tiered, risk-based climate control; energy-aware environmental strategies; formalized incident response workflows; and ethical collection governance addressing provenance, repatriation, and access-versus-preservation trade-offs.

1. Introduction

Museums hold their collections in public trust, which imposes a professional and ethical obligation to preserve cultural property while simultaneously supporting research, exhibition, education, and community engagement. According to the International Council of Museums, core museum responsibilities include stewardship, systematic documentation, accessibility, and

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responsible disposal, alongside explicit duties related to disaster preparedness, security, insurance or indemnity, and due diligence in acquisition and provenance research (International Council of Museums [ICOM], 2017).

Within this stewardship framework, collection management practices have progressively evolved from isolated, object-focused conservation treatments toward a preventive and systems-based approach. Preventive conservation emphasizes the management of environmental conditions, storage systems, handling procedures, documentation processes, and institutional workflows in order to reduce deterioration risks before active conservation interventions become necessary. The Canadian Conservation Institute formalizes this approach through its widely adopted "agents of deterioration" framework, which identifies ten primary categories of risk—such as inappropriate relative humidity and temperature, light exposure, pests, pollutants, physical forces, fire, water, theft or vandalism, and dissociation—and links them to structured strategies of detection, blocking, and response (Canadian Conservation Institute [CCI], 2025).

Among these preventive measures, climate control and environmental monitoring play a particularly critical role in safeguarding collections. However, these practices are frequently misunderstood as fixed or legally binding standards. The CCI clarifies that most heritage institutions operate within flexible guidelines and technical specifications rather than enforceable legal climate standards, with specific environmental requirements often arising from loan agreements, accreditation frameworks, or institutional policy rather than statutory regulation (Canadian Conservation Institute, n.d.).

Compounding these challenges, climate change is significantly reshaping risk profiles for museums worldwide. Increasing frequencies of heatwaves, flooding events, humidity fluctuations, and pollution episodes intensify both operational pressures and long-term threats to collections. Recent research focused on museum environments demonstrates that climate variability and rising pollutant loads necessitate adaptive, region-specific resilience strategies, moving beyond static environmental targets toward dynamic, risk-informed preventive conservation models (Dimabayao et al., 2025; Lucchi, 2024).

2. Literature Review

Contemporary preventive conservation literature can be broadly grouped into three interrelated domains: (a) environmental specifications for collection care, (b) risk management frameworks for prioritizing mitigation actions, and (c) organizational and ethical governance mechanisms that integrate facilities management, collections stewardship, and public access.

Environmental specifications are largely informed by professional engineering guidance and technical standards. One of the most influential frameworks in museum building and facilities practice is provided by the American Society of Heating, Refrigerating and Air-Conditioning

Engineers through the *ASHRAE Handbook—HVAC Applications*, particularly the chapter addressing museums, galleries, archives, and libraries. This guidance defines graduated environmental control classes (AA to D), specifying outer limits for temperature and relative humidity, allowances for seasonal drift, and acceptable short-term fluctuations. Importantly, ASHRAE emphasizes that strict environmental control is justified primarily for highly sensitive or “unproofed” objects, while noting that system reliability and consistency may be as critical as narrow control bands themselves (American Society of Heating, Refrigerating and Air-Conditioning Engineers [ASHRAE], 2019).

European and international standards complement this engineering-oriented perspective with object-centered analytical approaches. EN 15757:2010 focuses on the mechanisms through which temperature and relative humidity variability induce mechanical damage—such as fracture, deformation, and delamination—in organic hygroscopic materials, including wood, paper, textiles, leather, bone, ivory, and paintings. The standard underscores that many objects have acclimatized to long-standing indoor environments and may therefore tolerate individualized climate ranges rather than uniform setpoints, challenging prescriptive environmental targets (European Committee for Standardization [CEN], 2010). Similarly, the International Organization for Standardization standard ISO 11799:2015 extends preventive conservation principles to archival and library collections, stressing the importance of stable indoor climates, high thermal and hygric inertia in building materials, pressure management strategies, and compartmentalization. It also highlights the escalation of microbiological risks above approximately 60% relative humidity and warns of increased brittleness at excessively low humidity levels (International Organization for Standardization [ISO], 2015).

Built-environment standards further emphasize that effective environmental control begins with site selection, building envelope performance, and systematic risk assessment, rather than reliance on HVAC systems alone. The British Standards Institution adoption BS EN 16893:2018 requires institutions to identify, mitigate, and periodically reassess risks when collections are housed within self-contained spaces inside larger buildings. The standard prioritizes passive environmental strategies where feasible and stresses the need for early expert consultation to reconcile conservation requirements with security, fire protection, and functional use (British Standards Institution [BSI], 2018).

Risk management literature in cultural heritage has increasingly converged on participatory and decision-support methodologies that aim to maximize preservation outcomes within finite resources. The ICCROM frames risk management as a structured evaluation of hazards, likelihoods, and consequences to inform mitigation planning and to balance competing objectives such as preservation versus access or preservation versus sustainability (International Centre for the Study of the Preservation and Restoration of Cultural Property [ICCROM], 2016). Building on this approach, the ABC method—developed in partnership with the Canadian

Conservation Institute—formalizes a cyclical process encompassing context establishment, risk identification, analysis, evaluation, and treatment, supported by continuous communication and monitoring. Integrated risk management is further conceptualized as coordination among emergency preparedness, insurance and liability, security, and collection management functions (Canadian Conservation Institute, 2025).

Recent literature on sustainability and climate action challenges uniform climate expectations and advocates energy-efficient, risk-based collection care. The Network of European Museum Organisations positions climate impact assessment, practical mitigation tools, cross-sector collaboration, and organizational embedding of sustainability principles as central to contemporary museum operations in a changing climate (Network of European Museum Organisations [NEMO], 2023). Complementing this perspective, the Getty Conservation Institute publication *Managing Collection Environments: Technical Notes and Guidance* conceptualizes sustainable environmental management as an interdisciplinary process that integrates climate physics, long-term monitoring and data interpretation, and institutional consensus-building, rather than adherence to rigid HVAC targets alone (Taylor et al., 2023).

Ethical governance forms the foundation of any comprehensive collection management system. The ICOM Code of Ethics requires museums to exercise due diligence in establishing complete ownership histories and to avoid the acquisition of illegally obtained or exported cultural property. It explicitly references international legal instruments, including the 1970 **UNESCO** Convention on the Means of Prohibiting and Preventing the Illicit Import, Export and Transfer of Ownership of Cultural Property, thereby linking ethical responsibility, legal compliance, and stewardship to documentation practices and public access policies (International Council of Museums, 2017; UNESCO, 1970).

3. Methodology

This study employed a structured narrative review with analytical synthesis, a methodology well suited to practice-facing scholarship in museum studies and heritage science. The primary objective was to integrate three complementary bodies of knowledge: (1) peer-reviewed research in museum and heritage conservation science; (2) international and national technical standards governing collection environments, storage, and safety; and (3) authoritative guidance issued by leading museum and conservation institutions addressing risk management, environmental monitoring, emergency preparedness, and ethical governance.

3.1 Search Strategy and Sources

The literature search covered the period 2010–2025, while also including foundational standards and guidance published earlier but remaining current and widely implemented, such as EN 15757:2010 and ISO 11799:2015. Sources were retrieved from publicly accessible publisher platforms, institutional repositories, and official organizational websites to ensure traceability and reliability.

The review incorporated the following source categories:

- **International standards and regulatory codes** (e.g., EN, ISO, NFPA) addressing repository design, environmental stability, fire protection, and collection safety (British Standards Institution, 2018; European Committee for Standardization, 2010; International Organization for Standardization, 2015; National Fire Protection Association, 2021).
- **Professional engineering guidance** applied in museum HVAC and environmental control practice, particularly the relevant chapter of the ASHRAE *Handbook—HVAC Applications* (American Society of Heating, Refrigerating and Air-Conditioning Engineers, 2019).
- **Institutional and sector guidance** issued by recognized conservation and museum bodies, including the Canadian Conservation Institute, ICCROM, the Getty Conservation Institute, NEMO, and the Smithsonian Institution (Canadian Conservation Institute, 2025; ICCROM, 2016; Network of European Museum Organisations, 2023; Smithsonian Institution, 2016; Taylor et al., 2023).
- **Peer-reviewed research literature** examining museum climate performance, energy efficiency, and the impacts of climate change on collection environments and risk profiles (Dimabayao et al., 2025; Elnaggar et al., 2024; Lucchi, 2024).
- **Ethical and legal frameworks** governing acquisition, provenance research, and international norms, including the ICOM Code of Ethics and the 1970 UNESCO Convention (International Council of Museums, 2017; UNESCO, 1970).

3.2 Search Terms

Core English-language search strings combined museum-related keywords with collection, environmental, and risk-management terminology. Representative queries included: *"museum collections climate control protocol," "ASHRAE museum RH temperature fluctuations," "EN 15757 organic hygroscopic materials," "heritage risk management ABC method," "environmental monitoring museum dashboard," "NFPA 909 museum emergency preparedness," "climate change museum collections risk analysis,"* and *"museum provenance due diligence ICOM."* Search terms were iteratively refined to capture both technical standards and applied conservation practice.

3.3 Inclusion and Exclusion Criteria

Sources were included if they (a) were peer-reviewed or issued by authoritative standards bodies or recognized heritage institutions, (b) addressed practical protocols for environmental control, preventive conservation, risk management, or emergency preparedness in collection settings, and (c) provided transferable guidance applicable beyond a single institutional context. Case studies were included where they offered evidence-based insights directly relevant to protocol design or risk prioritization (Elnaggar et al., 2024; Dimabayao et al., 2025).

Sources were excluded if they (a) consisted of non-authoritative summaries lacking methodological transparency, (b) focused primarily on commercial product marketing without substantive protocol guidance, or (c) addressed topics outside the core collection-care triad, such as exhibition design unrelated to environmental or collection risk. These criteria were applied to prioritize primary guidance and reduce interpretive bias arising from secondary commentary.

3.4 Synthesis Approach

The selected literature was synthesized into a protocol-oriented analytical framework reflecting current best practice in preventive conservation. This framework follows four sequential steps: (1) defining threats using the “agents of deterioration” model; (2) establishing climate control levels aligned with collection vulnerability and building performance; (3) operationalizing environmental monitoring, thresholds, and response procedures; and (4) integrating emergency preparedness, documentation systems, and ethical governance into routine collection management. This structured synthesis enabled cross-comparison of standards, guidance, and empirical findings while maintaining relevance to operational museum contexts (Canadian Conservation Institute, 2025; ICCROM, 2016; Taylor et al., 2023).

4. Findings and Discussion

Evidence drawn from international standards, institutional guidance, and recent peer-reviewed scholarship converges on a central finding: collection management is most effective when climate control, conservation practice, and risk management are treated as a single, integrated workflow, supported by shared data, clearly defined roles, and formal escalation pathways. Rather than operating as parallel or siloed functions, preventive conservation, facilities management, documentation, and emergency preparedness perform optimally when coordinated through common protocols and decision structures. This section synthesizes findings related to conservation planning, climate-control protocols, organizational risk governance, and emerging pressures linked to climate change.

4.1 Collection Management as an Integrated Workflow

Contemporary collections work encompasses acquisition ethics, documentation, environmental management, preventive conservation, and emergency preparedness, while also facilitating research access and public engagement. This holistic approach aligns with the stewardship principles articulated in the ICOM Code of Ethics, which situates documentation, accessibility, and disaster protection among the core responsibilities of museum governing bodies (International Council of Museums, 2017). Risk management frameworks similarly conceptualize integrated risk management as coordination among multiple institutional risk systems—such as fire protection, liability and insurance, business continuity, security, and collections care—rather than as discrete and independently managed plans (ICCROM, 2016).

A key implication of this convergence is that climate control cannot be treated solely as a facilities issue. Environmental performance is influenced by collection use patterns (e.g., loans, exhibitions, and handling frequency), the quality of documentation (including condition baselines), and the institution's preparedness to respond to excursions or disasters. The Smithsonian Institution's declaration on the collections preservation environment emphasizes that monitoring strategies and performance criteria should be defined at the earliest design stages, that monitoring systems should be integrated and automated where possible, and that resulting data must be accessible across departments—including collections, facilities, and senior management—to support coordinated decision-making (Smithsonian Institution, 2016).

4.3 Monitoring and Response: From Data Collection to Action

Across the reviewed literature, monitoring is consistently framed as a protocol-driven organizational capability rather than a technical device. Institutional guidance stresses that automated, integrated monitoring and shared access to environmental data are prerequisites for effective preventive conservation, enabling timely response and accountability (Smithsonian Institution, 2016). Engineering guidance further links environmental performance to building-envelope characteristics, system reliability, and operational practices, reinforcing that monitoring outcomes must be embedded in management processes rather than treated as isolated metrics (American Society of Heating, Refrigerating and Air-Conditioning Engineers, 2019).

An effective monitoring protocol therefore requires clearly defined sampling frequencies, quality-control procedures, alert thresholds, and escalation pathways that assign responsibility for response and documentation. Risk management literature emphasizes continuous monitoring, review, communication, and consultation as integral components of preventive conservation, ensuring that environmental data consistently informs decision-making and corrective action (ICCROM, 2016; Taylor et al., 2023).

Table 1. Climate control protocol parameters by collection type (indicative).

Collection type	Typical target temperature	Typical target RH	Acceptable fluctuation guidance	Monitoring frequency	Recommended actions when out of range
Organic hygroscopic materials (wood, leather, bone/ivory; many painted/composite objects)	10–25°C (avoid rapid swings)	35–65% RH (set around collection's historic average where feasible)	Short-term fluctuations tightened for high-vulnerability objects (e.g., ±5% RH, ±2°C under tighter control types); seasonal adjustments should be slow and justified	Continuous data logging (e.g., 5–15 min), plus monthly review of trends	If RH excursions occur: (1) identify source (HVAC drift, infiltration, leaks), (2) stabilize gradually to avoid stress cycling, (3) prioritize high-vulnerability objects for microclimates or relocation
Paper/textiles (archives, books, cellulose-based materials)	"Cool" conditions; avoid heat spikes	Keep below mold-risk thresholds; avoid both >60% RH and over-drying	Stability prioritized; avoid long exposure above ~60% RH (mold risk) and very low RH (brittleness risk)	Continuous logging plus periodic calibration checks	If RH trends upward toward mold-risk levels: deploy dehumidification, improve envelope/air sealing, and review storage density/airflow; if RH too low: mitigate over-drying and reassess HVAC settings
Metals (ferrous/non-ferrous; mixed metal objects)	Moderate, stable	Prefer mid/low RH; avoid high RH and condensation risk	Control focused on preventing high-RH episodes and condensation; critical RH can vary with metal type, salts, and pollutants	Continuous logging; add dew point/condensation risk assessment	If RH elevated: inspect for condensation sources; reduce infiltration; control humidity; consider microclimate enclosures for high-risk items; integrate pollutant control where relevant
Ceramics/stone/glass (generally less hygroscopic)	Broader tolerance; avoid extremes	Prevent dampness and very high RH	Wider bands can be acceptable where mechanical risk is low; focus on preventing dampness and mold-prone conditions in adjacent organics	Continuous logging in shared spaces; spot checks in cases	If persistent high humidity: prioritize building/source moisture control; ensure that mixed displays do not expose organics to dampness; document excursions and adjust building controls

Sources for Climate-Parameter Logic

The logic underpinning climate-control parameters in museum protocols is derived from a convergence of engineering standards and object-centered conservation guidance. The ASHRAE framework provides operationally actionable types of environmental control, defining outer limits, seasonal adjustments, and permissible short-term fluctuations for temperature and relative humidity. Under certain control categories, this includes ranges such as approximately 35–65% relative humidity and 10–25°C, while explicitly cautioning that tighter control is warranted only for highly sensitive or unproofed objects and that system reliability is a critical determinant of risk (American Society of Heating, Refrigerating and Air-Conditioning Engineers, 2019).

Complementing this approach, EN 15757 emphasizes the role of relative-humidity-driven mechanical stress in organic hygroscopic materials, including wood, paper, textiles, and composite objects. Rather than prescribing universal setpoints, the standard focuses on limiting damaging fluctuations and recognizes the significance of historical acclimatization, supporting climate ranges tailored to object behavior and long-term environmental trends (European Committee for Standardization, 2010). ISO 11799 extends preventive conservation logic to documentary heritage by highlighting the escalation of microbiological risk above approximately 60% relative humidity and increased material brittleness at low humidity levels, reinforcing the need to avoid both prolonged damp conditions and excessive drying (International Organization for Standardization, 2015).

Risk Management: From Hazard Lists to Defined Responsibilities

Risk management becomes operational only when it translates identified hazards into clearly defined responsibilities, decision authority, and escalation timelines. The ABC method conceptualizes risk management as a cyclical process and places strong emphasis on integrating emergency preparedness with other institutional risk programs, while maintaining a unifying objective: achieving the best possible preservation of heritage value within available resources (Canadian Conservation Institute, 2025).

Similarly, the ICCROM guide highlights risk management as a planning tool for navigating inherent dilemmas, such as preservation versus access and preservation versus environmental sustainability. By structuring decisions around likelihood, consequence, and mitigation feasibility, risk management enables transparent and defensible prioritization rather than ad hoc responses (ICCROM, 2016).

Fire Protection and Emergency Preparedness

Literature on fire protection and emergency preparedness consistently emphasizes that effective collection protection must coexist with life-safety requirements and institutional continuity. NFPA 909 (2021 edition) outlines a comprehensive protection program for culturally significant properties that integrates fire prevention, fire-protection system management, security, emergency preparedness, and the inspection, testing, and maintenance of protection systems. Recent revisions expand discussion of wet collections and vulnerability criteria, reinforcing the need for tailored emergency planning that accounts for material-specific risks and operational realities (National Fire Protection Association, 2021).

Table 2. Risk management steps and responsible roles (practice-oriented matrix).

Risk management step	Purpose in collection care	Typical responsible roles (example)	Key outputs / documentation
Establish context (scope, values, constraints)	Define what "loss" means (value, significance), time horizon, legal/ethical constraints, and operational limits	Director/Executive leadership; Head of Collections; Conservation lead; Facilities manager	Risk scope statement; collection significance/value articulation; policy constraints (e.g., access obligations)
Identify risks (agents of deterioration)	Systematically list threats: environmental, physical, security, documentation, and building hazards	Collections manager/registrar; Preventive conservator; Security; Facilities	Risk register mapped to "agents of deterioration"; asset inventory linkages
Analyze risks (likelihood × consequence)	Quantify or rank risks to prioritize resources; include uncertainty and underlying causes	Preventive conservator; Data/monitoring lead; Facilities engineer; Security	Risk analysis worksheets; environmental trend analysis; failure mode hypotheses
Evaluate and prioritize	Decide which risks must be treated first and what trade-offs are acceptable	Cross-functional risk committee (collections + facilities + security + leadership)	Prioritized mitigation plan; accepted-risk statements; budget/sequence plan
Treat risks (mitigation)	Implement preventive measures (building, HVAC, storage, handling, security, documentation)	Facilities; Conservation; Collections; Security; IT (re: data integrity)	Work orders; revised protocols; training records; updated storage plans
Emergency preparedness and response	Prepare for and respond to rare catastrophic events; triage, salvage, recovery	Emergency coordinator; Collections response team; Security; Facilities; external responders/insurers	Emergency plan; response kits; salvage priorities; post-incident report
Monitor, review, and communicate (continuous)	Ensure mitigation is effective; revise protocols; report to governance	Monitoring/data lead; Conservator; Facilities; Leadership	KPI dashboards; periodic audits; incident/action log; annual review

Anchoring Sources and Integrative Logic

Across the reviewed corpus, three sources function as conceptual anchors for protocol design: the "ten agents of deterioration" framework, which structures threat identification and prioritization; the ABC risk cycle, which operationalizes integrated risk management through iterative assessment and treatment; and NFPA 909, which extends collection care into comprehensive programs for security, fire protection, and emergency preparedness in cultural resource properties (Canadian Conservation Institute, 2025; ICCROM, 2016; National Fire Protection Association, 2021).

4.5 Sustainability and Climate Change: Operational Implications for Protocols

Sustainability has become inseparable from collection care, as energy consumption, carbon-reduction policies, and climate resilience increasingly shape feasible operating regimes for museums. Sector guidance emphasizes that climate impact assessment and the organizational integration of sustainability objectives are now practical necessities rather than optional enhancements. Collaborative, tool-based approaches are highlighted as essential to translating climate ambitions into operational change (Network of European Museum Organisations, 2023).

Peer-reviewed research reinforces that energy performance in museums must be evaluated in direct relation to collection preservation requirements and visitor comfort, and that environmental standards developed in one climate region may not be directly transferable to others. Lucchi (2024) proposes energy performance indicators tailored to air-conditioned museums in tropical climates and underscores the need to balance heritage preservation with energy efficiency as part of climate-change mitigation strategies.

Climate change also intensifies indoor environmental risks and increases pressure for resilience planning. Empirical risk analysis demonstrates that climate-driven temperature and relative humidity fluctuations, combined with pollution pressures, can accelerate degradation processes and raise conservation costs. Case-study evidence shows that these drivers necessitate preventive conservation plans adapted to local conditions and institutional resources, rather than reliance on generic targets (Elnaggar et al., 2024). Broader heritage-risk scholarship similarly advocates for systematic climate-risk assessment frameworks aligned with international risk concepts—hazard, exposure, and vulnerability—to improve comparability, prioritization, and actionability (Dimabayao et al., 2025).

4.6 Ethical Considerations: Provenance, Repatriation, and Access versus Preservation

Ethical governance fundamentally shapes what collection management must protect and why. The ICOM Code of Ethics requires rigorous provenance research and due diligence prior to acquisition, explicitly warning that evidence of lawful ownership does not necessarily constitute valid title. Stewardship is framed as encompassing documentation, accountability, and public accessibility, rather than physical care alone (International Council of Museums, 2017). The Code further directs museums to interpret ethical responsibilities in light of international legal instruments, including the 1970 UNESCO Convention on illicit import, export, and transfer of cultural property (UNESCO, 1970).

These ethical considerations have direct operational consequences. Risk-based decisions frequently involve trade-offs between access (exhibitions, teaching use, loans) and preservation constraints, particularly under climate-control limitations and sustainability targets. Risk management guidance explicitly acknowledges such dilemmas—between preservation and access, and between preservation and environmental sustainability—and emphasizes that protocols should include transparent criteria for acceptable risk, thorough documentation of decisions, and structured stakeholder consultation to maintain legitimacy and accountability (ICCROM, 2016).

5. Recommendations

The following recommendations are formulated as actionable, protocol-level practices applicable to museums of varying size and geography. They assume a mixed-collection institution with both storage and display spaces and should be adapted using local climate data, building performance characteristics, and collection vulnerability assessments.

5.1 Establish a Tiered, Risk-Based Climate Control Policy

Museums should explicitly select an environmental type of control based on collection sensitivity, acclimatization history, and the reliability of building systems, rather than defaulting to the narrowest achievable control band. ASHRAE guidance recognizes multiple control types (AA–D) and provides outer limits, seasonal adjustments, and short-term fluctuation allowances to support such tiering. It further clarifies that highly stringent control is justified primarily for very sensitive, unproofed objects (American Society of Heating, Refrigerating and Air-Conditioning Engineers, 2019).

Where climate-induced mechanical damage to organic hygroscopic materials is a principal concern—particularly in historic interiors and mixed collections—EN 15757 should inform protocol design. Its emphasis on strain–stress cycles and acclimatization supports approaches that prioritize stable trends and gradual adjustments over fixed point setpoints (European Committee for Standardization, 2010).

5.2 Treat Monitoring as a Governance and Workflow Function

Environmental monitoring should be implemented as a cross-departmental governance function rather than a purely technical add-on. A robust monitoring program includes defined sensor placement strategies, calibration schedules, data-access rules, alert thresholds, and an incident or action log. Institutional guidance emphasizes automated and integrated monitoring systems and the accessibility of data to all stakeholders, reinforcing the role of monitoring as shared infrastructure (Smithsonian Institution, 2016).

Museums should formalize escalation protocols for environmental excursions—for example, immediate notification of facilities staff, timely involvement of conservation personnel for sustained deviations, and documented root-cause analysis and corrective action within defined timeframes—aligned with the "monitor and review" principle of risk management cycles (ICCROM, 2016).

5.3 Build Risk Management Capacity through Integrated Planning

Institutions are advised to maintain a standing, cross-functional collection care and risk group comprising collections, conservation, facilities, security, and leadership. This group should regularly review risk registers, climate performance data, near-miss incidents, and mitigation progress. Integrated risk management, as articulated in the ABC method, enables coordinated decision-making across organizational risk systems and improves both efficiency and credibility (Canadian Conservation Institute, 2025).

Emergency preparedness should be embedded within this integrated risk framework. NFPA 909 outlines comprehensive programs encompassing fire prevention, security, emergency response, and protection-system maintenance, indicating that basic emergency plans should be developed into tested, trained, and maintained operational programs (National Fire Protection Association, 2021).

5.4 Embed Sustainability and Climate Adaptation into Collection Care Protocols

Museums should explicitly link environmental targets to energy-performance objectives and climate-resilience planning. Sector guidance frames climate protection as requiring practical tools, institutional integration, and collaboration, while peer-reviewed research emphasizes balancing energy reduction with preservation outcomes and recognizing the limited transferability of standards across climates (Lucchi, 2024; Network of European Museum Organisations, 2023).

Given the increasing frequency and intensity of climate extremes, protocols should incorporate scenario-based planning for heatwaves, flooding, and prolonged high humidity. Region-specific adaptation measures and clearly defined triggers for enhanced monitoring and emergency readiness are essential. Empirical risk analyses support this approach by linking environmental fluctuations and pollution pressures directly to preventive conservation planning needs (Elnaggar et al., 2024).

5.5 Sample Climate Control Protocol Checklist

A concise internal checklist can translate standards-based climate logic into daily practice by aligning environmental targets (ASHRAE, EN, ISO) with risk-management workflows. Such a checklist should cover threat identification, target selection, monitoring parameters, response thresholds, documentation requirements, and review cycles, forming the basis of a practical standard operating procedure adaptable to institutional context.

Table 3. Sample climate control protocol checklist (adaptable SOP template).

Step	Checklist item	Responsibility (example)	Frequency	Evidence/record
1	Define collection zones and material vulnerability (organic, paper/textile, metals, mixed)	Conservator + Collections manager	Annual; update after major acquisitions	Zone map; vulnerability notes
2	Document climate history (baseline trends, seasonal patterns, known excursions)	Monitoring lead + Facilities	Initial + quarterly review	Baseline report; trend graphs
3	Select control type and targets (e.g., ASHRAE A1/A2/B) consistent with building capability	Facilities + Conservator + Leadership	Annual or after renovation	Signed climate policy; setpoint document
4	Establish sensor plan (placement, redundancy, calibration schedule)	Facilities + Monitoring lead	Continuous; calibration per schedule	Sensor register; calibration logs
5	Set alarm thresholds and response times (T, RH, dew point/condensation risk; mold-risk thresholds)	Conservator + Facilities	Annual; validate quarterly	Alarm matrix; contact list
6	Implement response procedures for excursions (triage, root-cause check, corrective action, documentation)	Facilities (first response) + Conservator (impact assessment)	Per event	Incident/action log; corrective work order
7	Review data and risks (monthly quick review; quarterly deep review; annual audit)	Cross-functional team	Monthly/Quarterly/Annual	Meeting minutes; KPI dashboard
8	Validate against collection outcomes (condition reports; targeted inspections after excursions)	Conservation + Registrar	Quarterly; after incidents	Condition checks; treatment logs
9	Update protocol for sustainability and resilience (energy benchmarking, seasonal strategy, climate adaptation triggers)	Leadership + Facilities + Conservation	Annual	Updated SOP; resilience addendum
10	Training and drills (environmental excursions, flooding/wet collections, fire response coordination)	Emergency coordinator + Department leads	Semiannual/Annual	Training attendance; drill reports

6. Conclusion

This study demonstrates that collection management in museums is most resilient when conservation planning, risk management, and climate control are implemented as an integrated governance system, rather than as parallel or purely technical programs. Across international standards, institutional guidance, and peer-reviewed research, several convergent principles emerge. Climate control is most effective when it is risk-based and collection-specific, rather than automatically optimized for maximum tightness. Monitoring systems must be designed around data-to-action workflows, ensuring timely escalation and access for all relevant stakeholders, while risk management frameworks should explicitly coordinate preventive conservation with emergency preparedness, security, and documentation practices (American Society of Heating, Refrigerating and Air-Conditioning Engineers, 2019; Canadian Conservation Institute, 2025; ICCROM, 2016).

Climate change and sustainability pressures further intensify the need for adaptive protocols. Energy consumption and carbon-reduction objectives increasingly constrain feasible operating regimes, requiring institutions to balance environmental performance with collection vulnerability. At the same time, the growing frequency of extreme events—such as heatwaves, flooding, and prolonged humidity excursions—demands scenario-based preparedness and clearly defined response thresholds. Empirical museum and heritage science research confirms that fluctuating environmental conditions and pollutant pressures can generate measurable conservation risks and long-term costs, reinforcing the value of customized preventive conservation plans grounded in monitoring evidence and institutional resource realities (Dimabayao et al., 2025; Elnaggar et al., 2024; Lucchi, 2024).

From an ethical perspective, collection management protocols must extend beyond physical preservation to include provenance due diligence, legal compliance, and transparent decision-making regarding access versus preservation. The ICOM Code of Ethics and the 1970 UNESCO Convention together provide a normative framework for responsible acquisition, stewardship, and documentation, ensuring that conservation and risk practices uphold public trust as well as material integrity (International Council of Museums, 2017; UNESCO, 1970).

Limitations

This study is based on an analytical synthesis of standards, authoritative guidance, and selected peer-reviewed literature rather than original empirical monitoring or experimental research. The review is predominantly English-language and does not model the full variability of local climates, building envelopes, or highly specialized collection needs, such as cold storage for film or complex salt-contaminated archaeological metals.

Future Research Directions

Future research should prioritize: (1) comparative field evaluations of tiered climate-control strategies across different climate zones; (2) quantitative assessment of energy–preservation trade-offs using shared performance metrics; (3) validation of low-cost sensing, analytics, and decision-support workflows suitable for under-resourced museums; and (4) systematic integration of climate-adaptation risk assessments into routine collections governance and long-term budgeting.

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Received: 01.07.2025
Revised: 01.18.2025
Accepted: 01.25.2026
Published: 02.09.2026