Care and Conservation of Natural History Collections

Title: Collection environment

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Source: Carter, D. J. & Walker, A. K. (1999). Collection environment. In: Carter, D. & Walker, A. (eds). (1999). *Chapter 7: Care and Conservation of Natural History Collections.* Oxford: Butterwoth Heinemann, pp. 139 - 151.

URL: http://www.natsca.org/care-and-conservation

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Collection environment

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Introduction

The key to long-term preventive conservation in natural history collections is control of the collection environment. The benefits of an efficiently managed and well controlled environment include not only protection for the collection but also better working conditions for staff and visitors. Moreover, there will be less need for costly remedial conservation. In recent years there has been a great deal of investigation into the ideal conditions for storing collections (particularly for art and antiquities) with optimum conditions prescribed for a wide range of objects. many requiring sophisticated air-conditioning. environmental controls and monitoring systems. While such solutions may be the ideal answer, most curators and conservators have to work within severe budget constraints and their first requirements are simple, sustainable measures such as good hygiene and pest control regimes (see Chapter 9 on policies and procedures). Moreover, many collections, especially those in Europe, are housed in relatively old buildings which cannot accommodate large-scale air-conditioning systems, even if the resources were available to pay for them.

Cassar (1995) provides extensive guidelines for environmental management, emphasizing the need for forward planning, while recognizing the constraints within which many institutions operate. Useful advice on developing an environmental management plan based on available resources is given by Martin (1997). He makes the point that the first priority is to ensure that the building is structurally sound and weather-tight because, until this is achieved, there is little point in making internal improvements. A strategic approach to environmental management will ensure that the problems are understood and priorities assessed, so that the best possible use can be made of the resources available.

A simple approach to environmental management is to consider the various agents that influence it (see Chapter 9 on policies and procedures). Of the ten recognized agents of deterioration, nine (physical forces; fire; water; criminals; pests; contaminants; light and UV radiation; incorrect temperature: incorrect relative humidity) are directly relevant to the collection's environment. Control of these environmental agents may be achieved at the following levels: locality, site, building, room and storage units (Waller, 1995).

Locality

Changes in the location of existing institutions are often not feasible but the choice is critical when considering the building of a new facility that will house collections. Areas subject to extreme climatic conditions such as hurricanes and typhoons should be avoided. Although sometimes difficult to predict, it is wise to avoid areas that are particularly subject to vandalism, crime and civil unrest. Some protection can be achieved in this respect by siting buildings away from main centres of human activity but this must be weighed against the advantage of proximity to emergency services. These are unlikely to be so conveniently available if the building is on a site that is not central. Although good communications are important, avoid areas too close to major roads, railways and airports, or heavy industry, where even barely perceptible effects of continual vibration may cause long-term damage to collections. Such areas may also be prone to atmospheric pollution with contaminants likely to affect collections. In such cases a careful analysis of the nature of pollutants may be justified before planning proceeds (Wilthew, 1997).

Climate can be a significant factor in deciding on the location of a building. Thomson (1986) discusses world climatic zones in the context of museum environment and highlights some specific problems relating to particular areas. Not least is the problem of moving collections from one climatic zone to another, an important consideration if relocating a museum.

In the tropics, the most suitable environment will be well above sea level, preferably in a rain-shadow area, to avoid problems of high humidity. For example, in the experience of one of the authors (Walker), the Kenyan National Insect Collection (sited at 2000 metres above sea level; Plate 31) requires no airconditioning as long as good clay to clay maintenance is carried out by well trained staff. Certainly, humid coastal sites and locations that are susceptible to serious flooding should be avoided if at all possible.

Site

When considering a site for a new building, one of the most basic considerations will be its geology. This will indicate whether the land is capable of supporting the weight of the building and its contents without subsidence and will also affect decisions regarding drainage. Former use of the site should also be considered, as this may indicate the possibility of contaminated ground (e.g. infill sites and former factory sites). Water and incorrect humidity problems can be reduced by good choice of a site, which should be well drained and above the level of local water courses.

Although the choice of site is mainly applicable to new buildings, it is sometimes possible to modify an existing site to improve environmental conditions. Redirecting or improving drainage can prove to be a good investment, saving the cost of expensive humidity control in the building, made necessary by rising clamp, and reducing the risk of costly flood damage.

In some cases, it may be possible to reduce potential problems from high temperatures and excessive light by strategic use of trees for shade and other landscaping profiles. Cassar (1995) also points out that 'shelter belts' of trees can be used to modify the effect of wind on exposed sites. However, this must be considered in balance with the associated problems of pest control. While good landscaping and careful planning can produce an attractive site and a pleasant environment for those working there, planting close to the building should be avoided wherever possible as this may harbour and encourage a range of pests that could threaten the collection (see Chapter 8 on Pest management, prevention and control). Particular care should be taken to ensure that no trees overhang the building. Where there are gardens associated with an institution, it is recommended that the collections building should he surrounded by a wide strip of gravelled or paved ground to provide a physical barrier to pests.

Building

Most collections are permanently housed in buildings which may or may not have been purpose-built and there is little chance of rehousing them. However, there is a continuing need for the construction of new facilities, particularly in developing countries throughout the world. This provides excellent opportunities to create high quality, long-term storage facilities for collections, particularly if environmental issues are considered at the design and construction stage.

In discussing archive buildings Kitching (1993) identifies two fundamental keys to success: (1) to protect archives against all forces which might otherwise harm them; and (2) to promote the work and well-being of everyone (staff and the public alike) going about their business there. Archives and natural history collections have much in common, since both include material that is unique and irreplaceable, and buildings which house them must be planned and built for this specific purpose. The most important considerations for a collections building are that it is soundly constructed to protect the contents from the outside elements and to provide a stable environment within. In order to make such buildings viable in the long-term, they should have a low energy consumption and be easy and economical to maintain. Ideally any new building (or building to he converted) for collections storage should be detached and self-contained. Not only does this provide isolation from hazards in adjacent properties, it also provides all-round access for maintenance purposes and ensures that emergency services will have unhindered access to any part of the building.

Structure

Strong foundations are a prime requirement for buildings and those housing natural history collections are no exception. Foundations and floor loadings may require specifications for heaving loading, for example, where large volumes of glass jars and microscope slides are stored or where compactor units are installed. Ideally the foundations should be solid bedrock but, where this is not possible, piled foundations or a concrete raft sunk deep into the ground may provide the necessary stability. If old buildings are to he converted, the foundations must be checked to find out if they are strong enough to withstand extra weight loads. Subsequent settlement may cause cracks in the structure, leading to problems with damp and pest access, while compactor units that run on rails may cease to function properly.

Ideally the collections building should be constructed of durable materials such as brick or concrete with double-skinned or aerated block walls for insulation. It should have a monolithic floor (i.e. continuous concrete floor without gaps). Flooring materials should he inert and unlikely to decompose. Reinforced concrete floors should be screeded and sealed to prevent break-up of the surface and consequent dust. An easily cleaned, non-slip floor covering is recommended. In laboratories and other areas where chemicals are used, floor coverings should he resistant to spills. Build up of static electricity is possible due to the wrong choice of floor covering and this should be avoided in collections areas which may be particularly prone to this problem due to low levels of relative humidity.

Cracks and gaps in floors will allow ants to invade, particularly in the tropics, and collections can be ruined within a few days. In many tropical environments this is such a serious problem that the ground beneath the building should he treated to repel ants and termites and, if practicable, a water trough could he constructed around the perimeter of the building as an added precaution against ant attack. For other aspects of building design that affect pest control see Chapter 8 on pest management, prevention and control.

Roofs

The building shell protects the contents against external forces, particularly weather. The first line of defence for the collections environment is a secure roof and great care should be taken in its design and maintenance. It is a good principle to keep the roof line as simple as possible, as too many roof levels result in valley gutters and complex drainage systems, which lead to maintenance problems and subsequent leaks and damp walls. A pitched roof is preferable to a flat one, mainly because it is less susceptible to leaks, but also because it provides fewer nesting sites for birds (a major source of pest infestations). Glass roofs and skylights, which are vulnerable to breakage and leaks, invariably lead to problems and are not recommended. Where they exist in old buildings, the glass should be reinforced and carefully sealed. Problems of temperature fluctuations and light levels can be reduced by installing blinds and UV filters. Overhanging roofs provide shade for the walls and help to reduce temperature and light levels within the building.

Windows

Ideally, collections storage areas should not have windows, but for various reasons this is not always practical. Windows should be double-glazed in toughened glass and, where good daylight is not essential for working purposes, they should be installed as high as possible and deeply recessed in the walls to minimize heat gain or loss and to reduce glare. It may be necessary for at least some windows to be openable for ventilation purposes but it is recommended that these are protected by mesh to prevent the entry of birds and insects. In the wet tropics, particular care should be taken to ensure that windows open upwards and outwards to stop tropical downpours entering the building.

Drainage and damp prevention

Rain-water must be channelled away from the roof as quickly as possible. All drain pipes should be external and easily accessible for maintenance. Blocked gutters and drains are often a cause of flooding and clamp problems, and these should be protected by mesh covers wherever possible.

It is essential that all areas are adequately drained, but basements are particularly susceptible to flooding and dampness and should not be used for storage of any collections if it can be avoided (see Appendix IV dealing with a case study). Drainage systems should be equipped with non-return valves to prevent back-flooding. Damp basements can sometimes be improved by sealing them with a waterproofing layer (tanking) but this is not always entirely successful and professional advice should he sought if such measures are necessary. Short-term local improvements may be achieved by the use of dehumidifiers.

Fire

A primary consideration in designing a new building or modifying an existing one is fire protection. Although most curators and collections managers are well aware of many of the risks involved, Wilson (1995) recommends that a thorough risk assessment should be carried out by a qualified fire protection engineer or similar specialist in consultation with museum staff. It is generally recognized that brick, stone and reinforced concrete are the most suitable building materials. Steel is widely used in reinforcing buildings but it should be borne in mind that it is a good conductor of heat and may conduct heat throughout the building in the case of a serious fire.

Timber and other flammable materials such as wall and floor coverings should be kept to a minimum and those that are highly combustible avoided altogether. In older buildings where full fire resistance of materials is not feasible, other fire precautions must be redoubled to compensate for this.

Smoke and water damage are often the most serious results of a fire. Smoke is exceedingly difficult to exclude but all air-conditioning systems should have self-closing ducts and rooms should be protected by self-scaling fire-doors. Lift shafts may act as chimneys and should not open directly into collections areas. To reduce the danger, they should be protected by fire doors.

It is important to be able to isolate areas in the case of fire, particularly those at greatest risk such as laboratories and storage areas that contain high volumes of alcohol. Compartmentation may be the best way to achieve this although, without careful design, it may lead to inefficient use of space.

Detection and control systems

All parts of the building should be equipped with smoke detectors linked to a central alarm system. Fire extinguishers should be available to deal with small fires and must be of the correct type to deal with the nature of the fire (e.g. CO2 extinguishers for electrical fires). Prompt action on site can prevent enormously costly damage to collections. A fire officer should be appointed to implement an emergency strategy in collaboration with local emergency services (see Appendix III on disaster planning). Automatic systems for fire control are based on water, foam or gas, but all have their drawbacks. Wilson (1995) provides a useful overview.

Water sprinkler systems are relatively cheap and efficient but carry some risk of water damage to collections and have traditionally been avoided for this reason. However, modern, computer-controlled sprinklers employ a 'dry pipe' system where water only enters pipes where sensors have detected a fire. In this way water is only delivered to the area immediately affected by the fire and this type of fire control is now considered to be the best option for most natural history collections.

Foam-based systems operate on the principle of starving the fire of oxygen by smothering it in a dense layer of high-expansion foam. Whilst effective, they cause a great deal of mess and carry the danger of asphyxia unless time is allowed for staff to escape before the system operates. Such a system is not considered viable for collection areas.

Gas-based systems present less of a hazard to collections and are operated by many museums and institutions throughout the world. Halon and CO_2 gases have both been used with success although the former is now considered to be a `greenhouse gas' while the latter is known to damage the ozone layer. Another problem is the risk of asphyxiation to those working in the collection area, so adequate time must be allowed for their escape before the system can be operated. As the gas is released under pressure, there is a risk that small items may be swept off tables and open shelves.

Separation of functions

When designing a new building, priority must lie in the provision of secure custody for the collections in a controlled environment. It is useful to segregate functions that require different degrees of security, environmental control and human comfort, but the prime concern must be to protect the collections areas. Plant rooms should always be positioned well away from collections to minimize the physical effects of vibration and risks of accidental fires. Similarly the siting and isolation of such areas as reception rooms and cafeterias must be carefully considered. Provisions should be made for a quarantine area for incoming material, again sited well away from the collections. A separate packing room is also an advantage, particularly if all packing material is stored there rather than in the collections areas as so often happens. Individual collections areas may also benefit from segregation. For example, it is not recommended to store animal hides in close proximity to an insect collection because of the risk of cross-contamination by pests.

Security

When designing a new building or considering an old one. security must be regarded as of prime importance. It offers the greatest protection for collections from physical forces, criminals and fire, and an alarm system should be in place, ideally hacked up by security patrols. The presence of unauthorized or unsupervised persons in a collections area, for whatever purpose, may have disastrous effects. For instance, an accidental fire caused by a careless or unsupervised worker can be just as devastating as deliberate arson. Although thefts from natural history collections may be relatively infrequent, it is often the rarest and most historically important specimens that are the target of unscrupulous collectors and are therefore most at risk. It should also be remembered that computers, cameras and even microscopes (and other research equipment) may attract thieves. The threat from damage by vandals must also be considered, although such motiveless actions are impossible to predict and can be difficult to prevent.

All potential entry points into the building must be considered and secured. External doors should be fitted with secure locks and accessible windows locked or barred. In areas prone to civil unrest, it may be advisable to fit windows with anti-shatter film. Vents, chimneys and inspection hatches should also be secured. Fire escapes and drain-pipes may all provide means of access and should be taken into account, the latter kept away from windows or treated with anti-climb paint if considered a security risk. Keller and Willson (1995) provide a structured approach to security systems.

Environmental control

To some degree the environmental conditions within a building can be controlled by a good choice of construction materials. Materials of high thermal mass such as stone or concrete, combined with good insulation (e.g. thermalite blocks and mineral-coated fibreglass sheeting) and natural ventilation provided by cavity walls, will buffer conditions to such an extent that air-conditioning systems may not be required (Kitching, 1993).

In the wet tropics, however, air-conditioning may be the only solution to environmental control. Such systems are prone to breakdown and a secondary system of ventilation, using openable windows and vents, must be available. Orientation of the building can be important to avoid the effects of direct sun raising the temperature of collections areas. This may be a particular problem in the tropics, while in many locations special consideration may need to be given to the availability of sufficient natural light for examination of specimens.

These problems can usually be overcome by good building design.

Balancing and controlling air-conditioning systems is always difficult and a system that performs well under cold and dry conditions may be inadequate when conditions become hot and damp. However good the system, it will not be successful if the building is in poor repair (e.g. gaps in roofs and window frames). Air filtration may be considered necessary in some highly polluted areas, although little is known about the effects of pollution on natural history collections.

Systems that function poorly may cause more harm than good. For example, a fault may raise instead of lower relative humidity, leading to mould growth, while incorrect insertion of filtering screens may lead to dust and other pollutants being blown through collection areas. Poor specification of environmental control systems can lead to `sick building syndrome' while inadequate maintenance can lead to staff illness (e.g. *Legionella pneumophila* in air-conditioning systems). In most cases, simplicity is the key to good air-conditioning systems. Over-specification may be profitable for the contractor supplying the system but does not necessarily lead to good environmental conditions.

Electrical and other service systems should be easily accessible so that regular maintenance is encouraged. Wherever possible, all service systems should be kept outside of collections areas. Concealment of pipes and conduits behind false ceilings and panels is to be avoided as faults may only be noticed after a serious failure, for instance a pipe beginning to leak. Moreover, false ceilings and partitions are potential dust traps and harbour pests. Water pipes in roofs and ceilings should be avoided wherever possible and should never run above collections. One of the authors had the unforgettable experience of a mains-fed water pipe bursting in the ceiling of a collections area. It was only because of a well designed and maintained drainage system, and the fact that the emergency was discovered at an early stage, that a potential disaster was averted. Hilberry (1995) provides a useful practical check-list of planning considerations for those involved in the construction of a new building or modification of an existing facility for storage of collections.

Room

Ideally, working collections (or stored collections) of natural history specimens should be kept in separate, custom-designed store-rooms where the optimum environmental conditions can be maintained. Separate study rooms can be provided in adjacent areas and maintained at a comfortable temperature with higher lighting levels. In fact, collections stores should not have windows and artificial lighting should be switched off when the collection is not in use. Moreover, separate collections stores are much easier to seal off for fumigation and anoxic treatments. Automatic sliding doors are recommended at access points as there will be less risk of dropping specimens while attempting to open and close doors by hand. To discourage the use of these stores for purposes other than the examination of specimens, they should be equipped with high benches which allow storage containers or specimens to be put clown easily without providing the temptation to use the area as a temporary office.

Although collections are ideally kept apart from working areas, this is often not possible, so that every effort must be made to find a compromise which will create tolerable working conditions whilst providing maximum protection to the collections. Lighting should be kept to the minimum for safe handling and examination of specimens. All windows should be equipped with blinds to control light and heating levels.

Temperature

Different types of collections may need to be stored at different temperature and relative humidity ranges. Mathias (1994) recommends temperature levels at which we feel most comfortable at work (i.e. 18-20°C). However, he also notes that, where possible, a cooler environment would be beneficial to specimens (the higher the temperature, the higher the rate of damaging biological activity and chemical reaction) and recommends that unoccupied stores could be maintained at 13-15°C. However, it should be borne in mind that objects moved from cold store-rooms to warmer study areas may be subject to condensation and other problems.

'Zoning' of collections is a useful option for different types of specimens which require different environmental conditions. For example, fluid-stored collections particularly benefit from low temperature storage, which not only reduces evaporation but also slows down the rate at which specimens deteriorate (Masner, 1994). Some curators store the most vulnerable part of their alcohol collections in refrigerators or freezers. Ideally, such collections should be maintained in a separate facility, such as the purpose-built system at the Royal Botanic Gardens, Kew, where there are separate collections and preparation areas maintained at different temperature levels.

Relative humidity

For most natural history collections, a relative humidity range of 40—50% would seem to be ideal (Morse, 1992), although in practice this is seldom achieved. Usually a dry environment is preferable to a humid one and a major concern, particularly in the wet tropics, is to maintain relative humidity levels below 60-65%, above which there are likely to be problems of mould growth. On the other hand, low relative humidity (below 30%) may cause shrinkage and embrittlement of specimens and adhesives. However, the worst problems are caused by extreme fluctuations in relative humidity, which can cause considerable damage both to specimens, for example cracked skins, tusks and horns (Plate 21), and to wooden cabinets and containers, for example warping and splitting (Fig. 7.1), leading to pest infestations. Local control of environmental conditions may be achieved by the use of portable humidifiers, dehumidifiers and heaters, but particular care must be given to their maintenance if fires and floods are to be avoided. The use of individual heaters (fan heaters) in winter may initially lower relative humidity but, when the heaters are turned off, there will be an increase in relative humidity before equilibrium is re-established. Before air-conditioning was available, an inexpensive answer to high humidity problems in the tropics was the installation of a low-wattage light bulb in the bottom of cabinets. However, there are serious concerns about the fire risks of this procedure.

Ideally, storage cabinets should be arranged as an island or islands in the middle of the room, away from walls. Where this is not possible, collections should at least be kept away from external walls. In our experience, where private collections are kept in ordinary domestic situations, it is those collections situated against external walls that suffer from mould attacks.

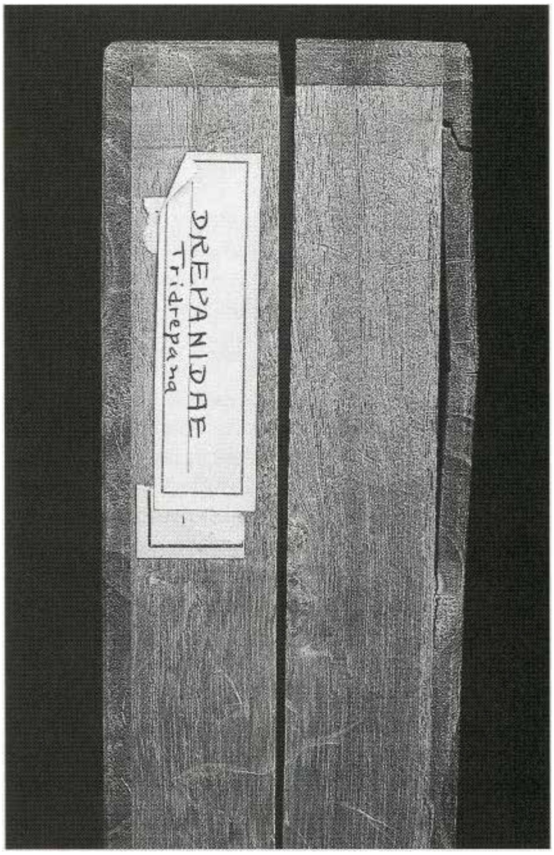

Figure 7.1 Wooden insect store-box which has warped and split due to extreme changes in temperature.

Prevention of infestation

In the case of certain institutions (e.g. field stations and agricultural laboratories), there is every likelihood that fresh and living material may be brought in from the field or kept in rearing cages. Such material may well harbour or encourage pests (cockroaches, mice etc.) which could infest the collection, and every effort must be made to keep it in isolation. For the same reason it is recommended that all living material, including pot plants, should be excluded from rooms that contain collections or in which collections are handled. Field collecting equipment should also be stored in isolation. Collections rooms should be easy to clean and should not be carpeted.

Storage Units

The storage unit provides the first line of defence for collections. Moore and Williams (1995) illustrate a wide range of storage systems and provide a useful table linking storage type with levels of protection from various agents of deterioration.

It is essential that storage units should provide protection from physical forces. Cabinets and drawers can give good protection but care should be taken to cushion vibrations that may occur when shutting drawers and doors. Ideally all drawers should have high density foam `buffers' at the rear for this purpose. Old cabinets often have felt fitted for this purpose but it is extremely vulnerable to pest attack. Traditional methods of providing support for specimens within storage units, using materials such as acid-free tissue, are still effective but modern materials such as sculpted polyethylene foam are now being widely adopted. In countries where earthquakes and violent storms are a hazard, shelves should have raised lips and storage units should be placed well hack from the edges, with restraining straps or chains used to secure them.

All specimens should be kept away from light to prevent deterioration of colour and other light-induced degradation (Plate 33). Storage units should ideally have solid wooden or metal doors but, where glazed doors need to be used, these should be constructed with UV-filtering glass or covered with sheets of UV-filtering plastic.

Cabinets should not stand directly on the floor but should be on raised plinths to provide ventilation and some measure of protection from minor floods. Ideally these should be open so that it is possible to clean under them but, if this is not possible, provision should be made for treating these areas with a residual insecticide such as Drione (see Chapter 8 on pest management, prevention and control). In tropical countries it may be necessary, to have cabinets with feet in cans of oil (or water in the short term, although this may cause problems with relative humidity) to stop ant infestations.

Cabinets

There has been some debate over the relative merits of wooden and metal cabinets for storing collections and both have their adherents. Wooden cabinets have been used traditionally, constructed of mahogany or some similar tropical hardwood. These have provided good service and are still widely in use today although modern cabinets and drawers are usually made of laminates and composites in conjunction with timbers from renewable resources. Most woods (particularly oak) are known to release organic acid fumes and these may damage some biological material such as mollusc shells (see the notes on Byne's disease in Chapter 2, p. 57) and birds eggs. Morse (1992) also suggests that such acids can promote metal pin corrosion in insect collections. On the other hand, wooden cabinets are regarded as good buffers against fluctuation in temperature and relative humidity. Moreover, when part of the botany collection in The Natural History Museum, London was hit by an incendiary bomb during wartime causing an extensive fire, many herbarium sheets stored in mahogany cabinets were simply charred around the edges with minimal damage to specimens (Moore, 1994) (Fig. 7.2 and Plate 23). If these specimens had been stored in metal cabinets they would almost certainly have been incinerated.

Metal cabinets have the advantage that they are cheaper to make and much more reliable in consistency (a problem with wooden cabinets) but metal drawers are more costly. It is also easier to make a metal cabinet that is virtually pest-tight. In Australia, insect drawers are constructed of steel but these are rather heavy and an American design utilizes aluminium although this is expensive. Plastic drawers made for use in The Natural History Museum, London were far from satisfactory clue to problems of design and static electricity charging. Von Endt *et al.* (1995) provide useful guidelines for evaluating materials for use in the construction of storage units.

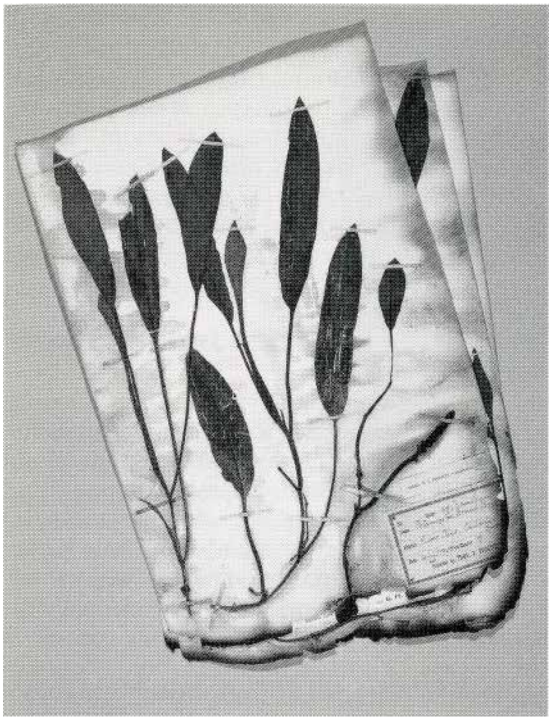

Figure 7.2 Herbarium sheets which were damaged by fire during the Second World War at The Natural History Museum, London. The wooden mahogany cabinet in which they were stored was subjected to intense fire due to an incendiary bomb. Note that the sheets have only been charred around the edges with minimal damage to the specimens. If they had been stored in a metal cabinet it is almost certain that they would have been incinerated.

Compactor systems

Compactor systems (Beelitz, 1995) have largely been devised as space savers, although the amount of space saved is not great, particularly in heavily used collections where sufficient aisles must be provided to permit access. Some institutions consider them to provide extra protection from dust and pests by utilizing sealing strips or gaskets around the edges (Fenner, 1992). The greatest hazard is the likelihood of mechanical damage to specimens as units move. This can be caused both by vibration and by units impacting against one another, although the latter can be reduced by the use of buffers. It may be that some exceedingly delicate specimens should never be stored on compactor systems. Power-operated systems are not generally recommended as they are susceptible to breakdowns and a power failure can make the entire collection inaccessible. Man (1992) advocates the use of compactors for storing collections in the tropics, suggesting that the seal between cabinets helps to reduce fluctuations of relative humidity.

Alternative storage systems

Although ideally all natural history specimens should be stored in enclosed cabinets, this is not always practicable. Where the storage area is environmentally controlled and dust-free, it may be acceptable to store larger, robust specimens on open shelving. In other cases, it may be possible to protect specimens on open shelves by the use of waterproof and dustproof curtains. Such curtains should never touch the floor as they will gather dust and may soak up water if there is flooding. Very large items that will not fit into standard storage units may also be protected by waterproof and dustproof covers (Fikioris, 1992; Guynes, 1992).

Environmental monitoring

Environmental monitoring is an important step towards creating good storage conditions for collections (Weintraub and Wolf, 1995). It can provide early warning of conditions likely to cause the deterioration of specimens (Cassar, 1997) and can subsequently monitor the effect of remedial actions. Accumulated data should be retained as they may prove to be important for establishing environmental requirements for future buildings and improved strategies for controlling energy costs. Well presented data from monitoring systems can be invaluable evidence when submitting a case for financial investment in environmental control.

Monitoring programmes can be undertaken for temperature and relative humidity, air quality, light and UV radiation and pests. A wide range of equipment is available for monitoring temperature and relative humidity, ranging from simple impregnated paper

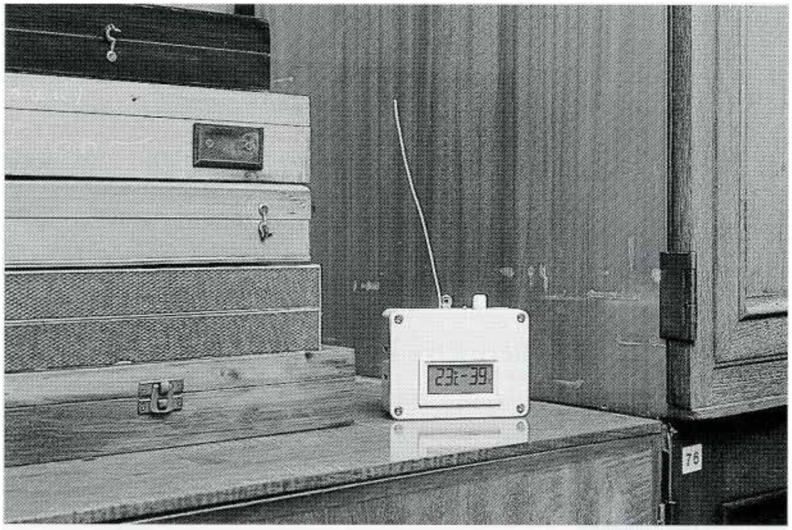

Figure 7.3 Telemetric equipment used in the Entomology Department of The Natural History Museum, London.

indicator strips to thermohygrographs and electronic data loggers. Thomson (1986) provides an overview and warns of the dangers of using such equipment without regular calibration, without which records will soon become meaningless. Modern telemetric systems (Fig. 7.3) using electronic sensors linked to a central receiving station provide a convenient answer to many of the problems of monitoring since, once installed, information is easily read, stored and interpreted using a computerized monitoring programme (Blades, 1997; Goodall, 1997). Recalibration is still required on a regular basis in order to maintain accuracy and consistency of records, but this is often provided as a service by the supplier. Such systems enable curators, conservators and collection managers to monitor atmospheric fluctuations with minimum involvement of staff time. Telemetric systems may also be used for monitoring levels of light and UV radiation, although this may only be necessary in display areas, since it is recommended that research and stored collections are normally kept away from light altogether. For assessing specific lighting situations, a range of metering systems is available (Thomson, 1986).

The cost of assessing air quality can be excessive and this is seldom carried out in natural history collections unless problems are suspected (Wilthew, 1997). According to Brimblecombe (1992), the slow degradation of biological materials produces a range of organic pollutant gases, some of which may cause damage to specimens. The major threat to natural history collections in this context is the release of carbonyl and carbonyl-containing volatile compounds from woods, adhesives and varnishes used in the construction of cabinets and display cases (Grzywacz, 1995). Where important collections of calcareous objects, such as shells are particularly at risk (see the note on Byne's disease in Chapter 2, p. 57), monitoring for carbonyl compounds should be considered.

Various forms of gaseous atmospheric pollution such as SO2 and NO7 may also cause degradation of some organic materials (Blades, 1997) although their effects on natural history collections have been little studied. However, it is known (Mathias, 1994) that high levels of SO2, the commonest pollutant in industrial areas, can lead to the degradation of preserved skins and organic fibres. Ozone is a highly reactive oxidizing agent that can damage most organic structures (Mathias, 1994). It does not normally present a serious problem in collection areas but care should be taken in the siting of ozone generators such as photocopiers. Where monitoring for gaseous pollution is called for, it should be planned and carried out by experienced conservation scientists.

Particulate pollution in the form of dust can usually be monitored visually, although it may be necessary to analyse its components if it presents serious problems. Pollution of this type, as well as being unsightly can lead to specimen damage resulting from mould growth, grit abrasion or organic degradation (Mathias, 1994).

Pest monitoring is extremely important in collections areas and may be achieved using a range of trapping systems. These are detailed in Chapter 8 on pest management, prevention and control.

Displays and teaching collections

These collections present the greatest challenge in terms of providing an environment that is safe for specimens but visually aesthetic. Specimens usually need to be on constant view to the public during visitors' hours and there must be a balance between level of access and possible risk of damage to specimens.

Environmental impact on visitors and the collections

In museum galleries and other display areas, the presence of people can produce significant changes in the environment. Large groups of people create changes in levels of temperature, relative humidity and CO7 whilst walking and touching display cases cause vibration. Fluctuating numbers of visitors will cause similar fluctuations in environmental conditions. Even greater differences may occur between visitors hours and quiet hours when galleries are empty. To some degree, this can be compensated for by air-conditioning but the most effective way of overcoming the problem is by isolating display specimens in sealed exhibition cases. A well designed case can create a favourable microenvironment within by using materials that buffer against environmental extremes and fluctuations.

Some fairly simple measures can be taken to reduce the environmental impact of visitors on collections. Provision of cloakrooms will encourage visitors to deposit excess clothing and baggage. Not only does this mean that visitors will not become too hot, reducing the need for air-conditioning, but they will not be encouraged to carry unnecessary items into collections areas where they could cause damage. Such facilities are particularly important on wet days. Comfortable eating and drinking areas sited well away from displays will help to protect collections from litter and resulting infestations whilst also providing for the comfort of visitors. Many museums and galleries are now replacing their basement storage areas with cafeteria facilities and removing their collections to more secure environments. The better the facilities, the more likely visitors are to appreciate and respect the collections. It may be necessary to control visitor numbers in areas where particularly sensitive specimens are displayed. This sort of control has largely been exercised in collections of art and antiquities but could equally well be employed for natural history displays. If such restrictions are considered necessary, they should be fully explained, perhaps by way of a leaflet to the visiting public, who will usually appreciate the care that is taken of their heritage.

Exhibition cases

It is important that exhibition cases provide an attractive display whilst affording maximum protection to specimens. Cassar (1995) provides useful pointers to the requirements for display cases with respect to the level of environmental protection they can afford, although there is no direct reference to natural history displays. When designing and constructing display cases, the materials used must be thoroughly assessed and tested to ensure that they will not adversely affect the specimens. Since most cases are well sealed, there is a danger of the build-up of pollutants from certain materials (e.g. off-gassing of organic acid vapours from woods) (Von Endt *et al.*, 1995; Grzywacz, 1995), while in some instances the specimens themselves may release harmful substances. Changes in relative humidity may also cause problems with temperature fluctuations (e.g. due to increased visitor numbers). Where problems of this nature arise, it may be necessary to provide cases with controlled ventilation. Such problems can only be assessed by close monitoring of the environment within the case (see above). Whilst this may not be practicable for all display cases within an exhibition, sample monitoring of a few cases should be sufficient to indicate problems.

Illumination

Adequate illumination must be provided for viewing displays, while at the same time, minimizing the risk of fading and structural damage caused by accumulated levels of light and UV radiation. Mathias (1994) recommends that lighting levels around specimens on permanent display should be maintained at about 50 lux with complete elimination of UV. Many display cases use internal electric lighting which often remains in operation throughout visitor hours. Heat from lights in such cases can pose a risk to specimens, particularly those preserved in liquid. Not only does heat itself damage specimens but it also increases the damaging effects of light. One way of overcoming this, or at least reducing the problem, is to have lights on a time-switch so that they are only in operation when the specimens are being viewed. It must be emphasized that it is the cumulative effect of light rather than the brightness of the light which ultimately leads to damage. Small fibreoptic spotlights are now widely used in display cases because they provide a light source that is virtually free from heat and UV radiation. However, these can cause problems of glare when used with small, highly reflective objects such as metallic-coloured insects.

Sometimes daylight or the gallery's main lighting system may provide adequate and suitable illumination without the use of internal case lighting, provided that UV levels are kept to a minimum by use of appropriate filters on windows and light sources (Staniforth, 1992). Poorly arranged lighting will make specimens less visible even at higher illumination levels due to glare and reflections. Use of non-reflective glass, well shielded light sources and carefully sited display cases will help to overcome these problems.

Modern moves towards 'hands on' exhibits present an even greater challenge to the curator and conservator. In many instances, this means that specimens are no longer inside cases but are presented in open displays or dioramas, isolated from the public only by a simple barrier. Thus, the entire gallery area must be maintained to high environmental standards to prevent deterioration of specimens. When designing such displays, great care must be taken to ensure that vulnerable specimens are out of the reach of visitors. In some instances, specimens can be replaced by models in more accessible areas (Plate 23).

If specimens are being handled it is best to confine them to a special area away from the main displays, where visitors can be closely supervised by staff. Unless specimens are particularly robust, they tend to have a short `life-expectancy' and so the use of 'expendable' material is advised. This can be either low-quality museum material without data or items which can be replaced easily (e.g. feathers, shells, seed-pods etc., collected locally). Specimens that are not easily replaced must be treated in such a way that they can be handled without damage. The use of modern resins for embedding and other `irreversible' preparation methods such as silicone polymer impregnation (Coghlan, 1997) may be justified to protect teaching material from physical damage.

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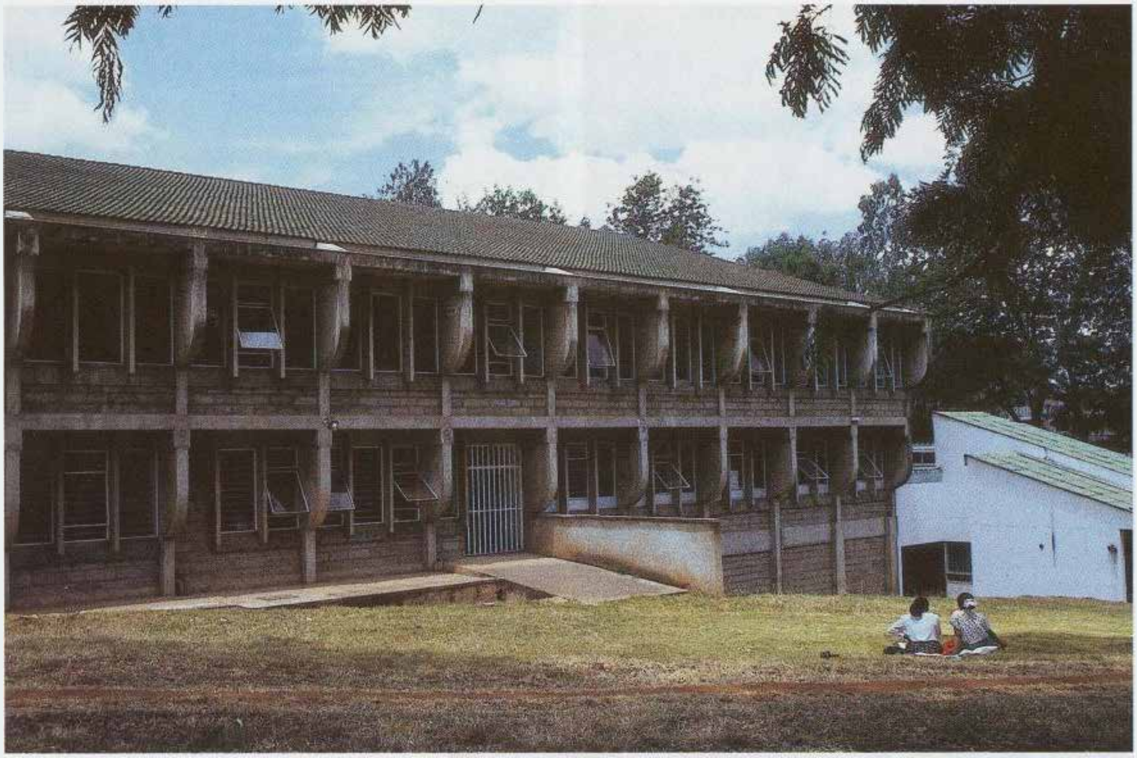

Plate 31 The National Museum of Kenya's purpose-built facility in Nairobi for housing the National Insect Collections. Note the absence of vegetation close to the building. Although the building is situated in the tropics it is considered high enough above sea level to avoid problems of high humidity. Natural ventilation is provided by the large opening windows (Annette Walker).

Plate 32 Part of a hippopotamus *(H. fi^agilis)* lower right canine showing splitting and delamination due to rapid changes in temperature and humidity (The Natural History Museum).

Plate 33 An example of the difference between keeping specimens subjected to intense light and keeping a specimen in the dark. Note how the framed moth specimen has lost most of its natural colour whereas the specimen kept in the dark has retained it (The Natural History Museum).

Plate 34 Where the lid is screwed on to the jar, the points of contact between the glass and the metal may wear the cellulose lining, exposing the metal which may then become susceptible to corrosion (The Natural History Museum).

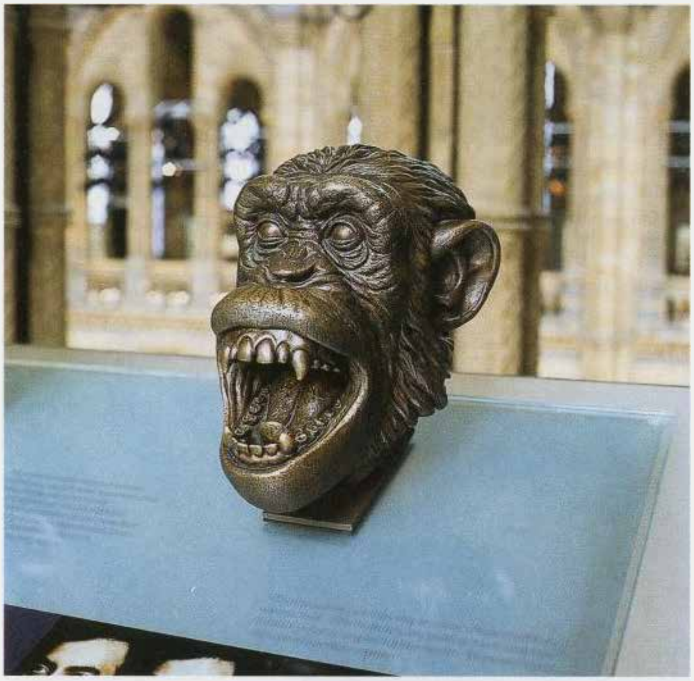

Plate 35 Primate exhibit at The Natural History Museum illustrating the use of a model which can be touched and felt by the public. Note how polished the jaws are, due to handling (The Natural History Museum).

Plate 36 An example of a vulcanized gasket on a LeParfait jar after approximately fifteen years in use. The cost of replacing these seals is considered to be minimal (The Natural History Museum).