



Department of **Biodiversity,
Conservation and Attractions**
Western Australian Herbarium

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Integrated Pest Management Plan

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**The Western Australian Herbarium
Science and Conservation Division
Department of Biodiversity, Conservation and Attractions**

Contents

Summary	1
Introduction	1
The Strategy	2
Monitoring	2
Physical Control	2
Environmental Control	3
Cultural Control	3
Education	3
Chemical Control	3
Handling of plant material in the KMCSC	4
Herbarium specimens	4
Disposal of plant material	4
Fresh material	5
Quarantine zones and activities	6
Green zone (high security)	6
Yellow zone (medium security)	6
Blue zone (low security)	6
How to guide for zones	7
Green zone (high security)	7
Yellow zone	7
Blue zone	8
General hygiene	9
Sanitation	9
Cleaning	9
Duties and tasks – Collections staff	10
Inspection	10
Monitoring and Trapping	10
Identification	11
Record Keeping	11
Maintenance of building	11
Temperature and Relative Humidity management	11
Duties and tasks – all staff and visitors	11
Reporting	11
Housekeeping	12
Appendix 1: IPM zones in the Keiran McNamara Conservation Science Centre	13
Appendix 2: Susceptible plant families	17
Appendix 3: Common Pests of the Collection	18
Herbarium Beetle, Tobacco Beetle, Cigarette Beetle (<i>Lasioderma serricorne</i>)	18
Drugstore Beetle (<i>Stegobium paniceum</i>)	19
Psocids, booklice (<i>Liposcelis bostrychophila</i> and <i>L. entomophila</i>)	20
Varied Carpet Beetle (<i>Anthrenus verbasci</i>)	21
Other pests of the Herbarium	22
Non-insect pests of Herbaria.	23
Appendix 4: What to do if a pest is located	24
Appendix 5: Herbarium Cleaning Schedule and Guidelines	27

This Integrated Pest Management Plan (IPM) has been produced by Karina Knight, Collections Manager, Western Australian Herbarium and Kevin Thiele, past Herbarium Curator with help and contributions from Cheryl Parker, Curation Supervisor.

Considerable assistance in developing this Plan was provided by the Managers of Australasian Herbaria Committee (MAHC), a subcommittee of the Council of Heads of Australasian Herbaria (CHAH). In particular, Dale Dixon, past Collections Manager at the New South Wales National Herbarium kindly provided copies of the NSW Herbarium IPM Plan.

This plan will be updated occasionally as necessary.

The most recent version can be found at <http://dbca.wa.gov.au/plants-and-animals/wa-herbarium>

Summary

This Plan establishes principles and practices for the handling of plant materials and other items that may harbour or encourage insect pests in the Keiran McNamara Conservation Science Centre (KMCSC), which houses the Western Australian Herbarium. Insects are one of the most important risks to the safety and security of the Herbarium's specimens, and adhering to this Plan will minimise the risk of insect damage to this irreplaceable State asset.

The document comprises an outline of the principles of Integrated Pest Management, instructions for the safe handling of plant material in the KMCSC, guidelines for allowable and prohibited activities in each of four designated IPM quarantine zones in the building, and an outline of staff and visitor responsibilities and duties under the Plan. Appendices provide maps of the zones, summary information on principal pest species and their identification and biology, and instructions for what to do if a pest is located or an outbreak suspected.

It is important that all staff working in the KMCSC and all regular visitors read and understand the requirements of this Plan and abide by its provisions. The Plan has been endorsed as Science and Conservation Division policy by the Division's Science Management Team.

Introduction

Under Western Australian legislation the WA Herbarium is required to maintain, build and ensure the safety of the State Collection of specimens of plants, algae and fungi and to increase and disseminate knowledge with respect to the plant life of Western Australia. The collection, which includes the type collection, is an irreplaceable State asset, and underpins conservation science in Western Australia.

Care of the collection is an important responsibility of the Herbarium and all its users. In the Keiran McNamara Conservation Science Centre (KMCSC) facilities we have established an Integrated Pest Management approach to this important task.

IPM combines careful and frequent monitoring of pest levels and environmental conditions with a combination of tools, procedures and strategies that are designed to mitigate the threat of pest damage to the Western Australian Herbarium's collection.

IPM allows staff working with the collection to be proactive rather than reactive to pest control. Ideally, the focus of integrated pest management is on habitat modification and exclusion to prevent pest damage rather than on control methods (such as poisons) to eliminate them. The approach is non-invasive and relies on the principles of monitoring pest activity, discouraging pests, modifying the environment and targeted treatments.

IPM is advantageous to the health and safety of the specimens, staff and the environment as it aims to prevent insect outbreaks and deal with any problems with minimal use of pesticides.

Any pest with chewing mouthparts is a risk to herbarium specimens, in either the adult or juvenile stage or both. Carpet beetles, clothes moths, storehouse beetles, cockroaches and others pose direct threats to specimens through feeding damage, faeces and excretions. Some pests pose indirect risks such as fires (rodents gnawing on wires) and secondary infestations (dead millipedes can attract carpet beetles).

Insect pests that damage herbarium specimens are regularly found within the herbarium facilities and the collection. Serious outbreaks have resulted in total or partial loss of some specimens.

All queries regarding the Integrated Pest Management Strategy and conditions affecting the safety and well-being of the collection should be directed to the Collections Manager, Karina Knight, Karina.Knight@dbca.wa.gov.au, (9219 9130).

The IPM strategy described in this document applies to the entire KMCSC building, although with greater levels of control in the Herbarium areas – the vaults and vestibules, offices and laboratories on the south side of the building. Appendix 1 outlines the IPM zones at the KMCSC.

The Strategy

Limiting the breeding of pests in a herbarium collection depends on an integrated approach ensuring that food is limited and environmental conditions are unfavourable for growth and reproduction. A regular building maintenance and cleaning program in all areas of the building enhances the effectiveness of integrated pest management. Preferred breeding sites for pests are any areas that remain undisturbed for long periods of time, where there is an available food source and where temperature and humidity are suitable for pests to persist and multiply.

The success of any integrated approach to pest management is to ensure that clients, visitors and staff are informed and educated about the uniqueness and importance of the collection. Pest outbreaks will occur; effective IPM ensures that outbreaks are located early, dealt with in a timely and effective manner and in a way that ensures minimal impact on the health and safety of the specimens, staff and the environment.

Six principles underpin effective and modern IPM: monitoring, physical control, environmental management, cultural practices, education and chemical control.

Monitoring

Regular observation is the cornerstone of IPM. Observation is broken into two steps: inspection and identification. Visual inspection, insect traps, and other measurement methods and monitoring tools are used to monitor pest levels. Accurate pest identification is critical to a successful IPM program. Record-keeping is essential, as is a thorough knowledge of the behaviour and reproductive cycles of target pests.

Physical Control

The most efficient method minimising pest damage to the collection is to exclude pests. Most pests arrive by being carried into the building, usually on infested

specimens, but they can also enter via packaging material etc. Trapping also acts as a physical control of pests, removing them from the population and reducing breeding opportunities.

Environmental Management

Modifying or manipulating the environment and making it less desirable or hostile for pests to live and breed will reduce pest infestations. Cool, dry conditions discourage pests from breeding. The environmental conditions of the specimen storage areas in the Herbarium (vaults, vestibules, Short Term Specimen Stores, Botany Store) are maintained at 16°C and 45% relative humidity (RH). The remainder of the building is maintained at a temperature conducive to humans (and pests).

Cultural Practices

IPM processes and procedures are designed to mitigate pest infestations and their spread. Herbarium pests are most active at night and therefore specimens left out on benches or in open boxes are at a greater risk of infestation.

Education

Success of any integrated approach to pest management depends on ensuring that clients, visitors and staff are informed and educated about the uniqueness and importance of the collection and the attractiveness of the specimens to destructive pests. The Herbarium provides the Integrated Pest Management Plan as an integral part of an induction process which includes how to detect and report pest activity. Staff will receive regular training and be informed of IPM changes or updates.

Chemical Control

There are many chemicals available to kill pests. Their use is viewed here as a last resort because:

- chemical control in the vaults is unlikely to be successful as the specimen boxes are closed and relatively impervious to chemicals.
- chemicals are harmful to humans and the environment

Chemical control is unlikely to be required at the Herbarium if the IPM controls outlined in this document are effective and rigorously adhered to.

The IPM strategy is reviewed annually by the Collections Manager and Curator, updated or modified as required, and changes communicated to users as appropriate.

Handling of plant material in the KMCSC

To mitigate the spread of pests that are harmful to herbarium specimens, plant material entering the KMCSC must be handled in one of the following ways.

Herbarium specimens

Plant material requiring immediate identification (via a request at reception)

- Seal each specimen separately in a snap-lock bag prior to entering the building. **Snap-lock bagged specimens must not be opened at any time within the Herbarium or**
- Immediately place the specimen in the Accessions Preparation Laboratory for processing

Plant material entering the Reference Herbarium

- Seal each specimen separately in a snap-lock bag **or**
- Freeze specimens (at the Herbarium) for a minimum of 24 hours at -18°C (refer to the *WA Reference Herbarium Visitor User Guide* for instructions on how go about this)

Plant material delivered for identification

- Freeze specimens (at the Herbarium) for a minimum of 24 hours at -18°C

Plant material forwarded by mail

Immediately upon opening of mail containing specimens, the plant material must be either:

- Sealed separately in a snap-lock bag (**snap-lock bagged specimens must not be opened at any time within the Herbarium) or**
- Placed in the Accessions Preparation Laboratory for freezing for a minimum of 24 hours at -18°C

Plant material for lodgement

- Freeze specimens (at the Herbarium) for a minimum of 24 hours at -18°C

Plant material requiring access to a vault for identification

- Seal each specimen separately in a snap-lock bag prior to entering the building. **Snap-lock bagged specimens must not be opened at any time within the Herbarium.**

Plant material for incorporation into a vault

- Freeze specimens (at the Herbarium) for a minimum of 24 hours at -18°C

Disposal of plant material

The Herbarium is registered as a Quarantine Approved Premise with the Department of Primary Industries and Regional Development (DPIaRD) and accredited to receive and handle plant material. Compliance with DPIaRD requires that all plant material is disposed of in a way that minimises the risk of diseases or seeds escaping into the environment. For this reason, all plant material for disposal must be placed in a

yellow MediCollect bin. Five MediCollect bins are available at the Herbarium for plant material disposal:

1. Accessions Preparation Laboratory – plant material from anywhere within KMCSO may be disposed of in this bin
2. Freezer anteroom (ground floor) – plant material from anywhere within quarantine areas Yellow and green may be disposed of in this bin (refer to ‘Quarantine zones and activities’ below for an explanation of the coloured zones)
3. Reference Herbarium – users of the Reference Herbarium must take home their plant material (including those in snap-lock bags), newspapers and boxes; only fragmentary plant material and sweepings may be disposed of in this bin
4. Mounting room – plant material from within quarantine areas yellow and green may be disposed of in this bin (refer to ‘Quarantine zones and activities’ below for an explanation of the coloured zones)
5. Curation Lab. level 2 - plant material from within quarantine areas yellow and green may be disposed of in this bin including disposal of loans packaging.

Snap-lock bagged specimens for disposal must be placed in MediCollect bins with the bag securely closed.

Fresh material

- Fresh flowers delivered to Herbarium staff must not be moved into the Herbarium areas, but stored in the Accessions Preparation Laboratory until collected and removed from the building.
- Fresh flowers for other staff members of the KMCSO should be disposed of appropriately as soon as they begin to wither.
- Fresh plant material used in other areas of the KMCSO such as the genetics laboratories should be disposed of carefully as soon as no longer required.
- Living plants (eg pot plants) are not permitted in the green and yellow zones (zones outlined below).

Quarantine zones and activities

The KMCSC is zoned into areas where different levels of quarantine apply. Some areas in the building are designated as high security quarantine/clean areas and have an extra layer of pest protection as insect outbreaks in these areas are more serious and difficult to control. Appendix 1 outlines the IPM zones at the KMCSC; in summary there are four zones.

Green zone (high security)

No specimens or plant material may enter and be exposed in this zone (on benches, workspaces, and in storage) unless it has been frozen. Unfrozen material may only enter this zone in a snap-lock bag which must remain sealed at all times and may not be stored in the zone.

Yellow zone (medium security)

Specimens that have previously been frozen (e.g. specimens removed from the vaults or Short Term Specimen Store) may be stored in this zone for short periods (days to weeks) while they are being actively worked on, but should not be kept for longer periods. Unfrozen material may only enter this zone in a snap-lock bag which must remain sealed at all times and may not be stored in the zone.

Blue zone (low security)

No herbarium specimens or other dried plant material which may harbour herbarium pests may be stored in offices and labs in this zone. Unfrozen, fresh or dried plant material may be exposed in this zone, but such material should be disposed of before it becomes a likely harbour for insect pests. Other materials that may harbour herbarium pests (e.g. dirty camping gear) should not be stored permanently in this zone. Living plants and fresh flowers may be kept in offices, but not dried flower arrangements.

Guides for zones

Green zone (high security)

The designated quarantine areas in this zone are the specimen storage vaults (vaults 1-4), type and loans room and ancillary rooms (vestibules). The following apply in these areas.

Movement into the vestibule from the corridor

Specimens, cardboard boxes, PERTH box, loans box, corrugated cardboards, backpacks and field journals entering the vestibule from the corridor must have been frozen immediately prior to entry. The following quarantine principles apply:

- Specimens entering directly from the freezer must be in either a PERTH box or a cardboard box enclosed in a bag (the bag ensures pests have not entered the box since freezing).
- Specimens entering which have not been frozen must be sealed in a snap-lock bag which must not be opened while in the vault or vestibule.
- Corrugated cardboards must be exchanged outside the vestibule door for red plastic trays.
- Trolleys must be clean – cleaned of any obvious debris.

Movement between a vestibule and its associated vault

Vestibules are considered annexes of their vault – free movement of specimens, cardboard boxes, corrugated cardboards and books between the vestibule and its associated vault is allowed without freezing unless the following applies:

- Specimens have been left unprotected out of a PERTH box overnight
- A PERTH box has not been closed correctly

In such cases place the specimens in their correct box, remove from the vestibule and place on a freezer trolley outside the nearest freezer.

PERTH boxes

PERTH boxes are pest proof and provide an important physical control to pest incursions. It is important that the box lid is closed at all times when the box is not in immediate use, particularly in non-quarantine areas (offices, laboratories, Short Term Specimen Store) where pests are more likely to be present. Quarantine areas are considered clean areas; however, the lid affords an extra layer of protection from pest incursion into the box. Keeping the lid closed is the simplest way to avoid pest damage to specimens.

Yellow zone

The designated areas in this zone are general work areas such as offices and laboratories, the Short Term Specimen Store and corridors within the Herbarium. The following apply in these areas.

Offices/Laboratories

- Maintain a minimum number of specimens in your office (i.e. the ones being currently studied)
- Store the remaining material in the Short Term Specimen Store
- Store specimens overnight in Short Term Specimen Store where practicable
- Close PERTH boxes securely that are not in immediate use

Once every six months Collections staff will organise to have offices attentively cleaned and all plant material stored in offices moved to the freezers for up to a week. All material from offices must be included in this freezing rotation. Two weeks' notice will be given of the impending freeze, to allow staff to prepare for the rotation. Note that small numbers of specimens that are required for immediate work may be frozen prior to the rotation and made available as soon as the remaining material is removed.

Short Term Specimen Store and Botany Store

This area is designed to store work in progress, either mounted or unmounted material. The benefit of this area is that specimens not ready to enter a vault or that are currently being studied are able to be stored in a climate-controlled area, affording some protection to the specimens from insects. The specimens will have been frozen on initial entry into the building, but can move freely between this area and other Yellow Zone areas without requiring further freezing.

Reference Herbarium:

- The door to the Reference Herbarium must remain closed at all times
- Refer to the *WA Reference Herbarium Visitor User Guide* for further specimen quarantine information.

Blue zone

The designated areas in this zone are the Herbarium specimen receival areas (including the Accessions Preparation Laboratory and Dryer room), the common areas in the KMCSC building including the atrium space, meeting rooms and canteen, and all offices and laboratory areas on the northern side of the building. The following apply in these areas.

Dryer room: This is a 'dirty' area, where fresh material is dried prior to processing. As un-frozen material is present in this room doors must remain closed at all times to minimize the spread of pests. Dryer protocols (available in the Dryer Room) must be adhered to, particularly in relation to the period a press remains in the dryer and the dryer cleaning regime.

Accessions Preparation Laboratory: This is a 'dirty' area, holding for short periods of time material that has entered the building unfrozen and is not yet processed. Doors into this room must remain closed at all times, particularly the door into the freezer anteroom, to minimize the spread of pests into the main building. Specimens must not be left on the benches etc, and must be processed as quickly as possible to avoid pests breeding.

All other areas: These are areas outside the direct control of Herbarium staff, including offices and laboratories on the northern side of the building. While work in these areas may require processing and storage of plant material, every care should be taken to reduce the opportunity for insect pests to breed. Fresh material may be brought into this area, but it should be processed quickly and not allowed to remain in a dry state. Dry plant material (e.g. silica-dried and freeze-dried material for DNA and other molecular studies) may be stored, but must be sealed in airtight and insect-proof containers. *Herbarium specimens must not be stored in this area.* Presses containing plant specimens should be placed in the Herbarium's Dryer Room or Accessions Preparation Laboratory and be handled as per normal Herbarium processes.

General hygiene

Hygiene is one of the most important aspects of an Integrated Pest Management system. Good hygiene makes many other aspects of IPM more effective and simpler to maintain. Adherence to and awareness of good hygiene practices is required of all Herbarium staff and visitors.

Sanitation

As well as herbarium specimens, pests are attracted to paper, wood, leather, wool, dust derived from organic material, human food (eg. nuts, dried fruit, chips, biscuits, tea etc), dead insects, fresh pollen and starch noodles used as packaging. The following sanitation principles apply:

- Food or liquids must not be taken into the specimen storage areas, vestibules, or specimen processing rooms.
- After eating or drinking, food scraps, crumbs and sticky food residues on surfaces must be cleaned up.
- Food (e.g. snacks and lunches) stored in offices for short periods must be sealed in plastic or glass, insect-proof containers.
- Food that must be stored for longer periods (e.g. camping stores) must be taken off-site, or when on-site, must be kept in a fridge or freezer (see Collections Manager for allocation of space in a freezer).
- The tea-making areas in the building must be kept neat and tidy at all times. All plant material (including tea-leaves, coffee etc) must be kept in sealed containers.
- Starch or synthetic packaging noodles must be disposed of and not recycled as packaging.

Cleaning

Good housekeeping is the responsibility of all staff. Herbarium pests thrive in areas that remain undisturbed and where there is an adequate food source. Bearing this in mind, offices and laboratories should be kept tidy at all times. This will also aid cleaning. The cleaning program of the Herbarium is regularly reviewed by the Collections Manager and includes an assessment of all rooms and areas in the building including stairwells. Refer to Appendix 5 for the Herbarium cleaning schedule.

Duties and tasks – Collections staff

The Collections staff are front-line staff for pest management and control, and have prime responsibility for ensuring the safety of the collection. Collection staff should be consulted by other staff concerned about a possible breach of this IPM plan or if insect outbreaks are noticed or suspected.

Inspection

Specimens: Visual inspection of specimens is not a routine task in the climate-controlled specimen vaults at PERTH unless pests are detected. Users will be instructed via an induction on how to recognise and report activity. If an outbreak is detected in the traps, known susceptible families will be checked randomly (families to check are listed in Appendix 2, *Susceptible Plant Families*). Specimens in all other rooms and specimen storage areas are inspected by Collections staff quarterly. Monitors should use a bright torch during inspections and look for live adults and larvae and the presence of shed larval skins or faeces. The presence of feeding debris or frass around or below specimens is an indication of infestation, as are exit holes, feeding holes, silken feeding tubes or cases, or moth or beetle pupae. A hand lens can be used to examine for eggs if an infestation is suspected.

Facility: Visual inspection of specimen storage areas, laboratories and offices will check for cleanliness and evidence of pests. Refer to *Sanitation* for further details. Window sills are inspected monthly as many pests fly or crawl to light. Pests may be found behind skirting boards, under furniture, behind mouldings, in cracks in floors or in air ducts.

Monitoring and Trapping

Electronic Insect Killers ('Zappers') emit ultraviolet light (black light) that attracts flying insects, particularly flies and moths. Insects are drawn into the trap, electrocuted and fall to a shelf, which is checked periodically and insects recorded. The traps must be checked and emptied regularly or the dead insects will themselves attract beetles and other scavengers. Zappers in specimen storage areas are on at all times and checked weekly; zappers in offices are on timers, operate between 6pm and 6am and are checked monthly.

Blunder traps are large sticky traps that catch crawling pests (including mice). They are placed on the floor just inside doorways against a wall, capturing pests entering the room. Capture rate will indicate if there are problems with pest exclusion in the building. Traps are checked and pest numbers recorded regularly, and replaced periodically.

Pheromone traps are sticky traps with a specific pheromone to attract certain pests. The pests are strongly attracted to the traps from the surrounding area, providing an extremely effective early warning system of pest presence. The Herbarium hasn't previously used this style of trap and won't initially in the new building; their use will be dependent on insect incidence. Pheromone traps are not recommended if an outbreak is not evident, as they also attract pests into the area.

Identification

Accurate identification ensures an appropriate understanding of the breeding and biology of the pest and the implementation of correct control methods. Insects trapped that are not identifiable or for which the identity is uncertain are forwarded to an entomologist at DPlARD for identification. Refer to Appendix 3, *Common Pests of the Collection* for aids to identification, information on biology of the pests and recommended methods of control.

Record Keeping

Careful records of inspection results, trap catches, etc. will help identify seasonal risk factors and areas with a high frequency of problems. Pests located in the traps are recorded in the *Pest Monitoring Database*. Random sightings or pest collection are the responsibility of all staff to report – capture the insect and forward to the Collections Manager. Report capture/sighting by emailing the Collections Manager, recording where the pest was located, the date and any other relevant information. Infestations on specimens are treated in the manner outlined in Appendix 4 *What to do if an outbreak is located*.

Maintenance of building

Regular inspection of the building is undertaken to ensure physical barriers to pest ingress are maintained and replaced as necessary by checking that doors close properly, insect barriers (door brushes) around doors are fitted correctly and still working, and zappers and timers are working.

Temperature and Relative Humidity management

Cool, dry conditions discourage pests from breeding. The environmental conditions of the specimen storage areas in the Herbarium (vaults, Short Term Specimen Store, Botany Store) are maintained at 16°C and 45% relative humidity (RH). The remainder of the building is maintained at a temperature conducive to humans (and pests). Rather than relying on Building Management System temperature and humidity settings, dataloggers are used to independently monitor temperature and relative humidity in specimen storage vaults, allowing instant and accurate monitoring and a faster reaction time when systems break down.

Duties and tasks – all staff and visitors

While the Collections staff are front-line staff for IPM, all staff should be aware of insect pests and vigilant for possible outbreaks, and are required to adhere to the housekeeping and quarantine principles and practices outlined in this Plan.

Reporting

Immediately inform Collections Manager of an observed live pest or evidence of pest activity. If possible capture the pest and report where it was captured, the date and any other relevant information.

Housekeeping

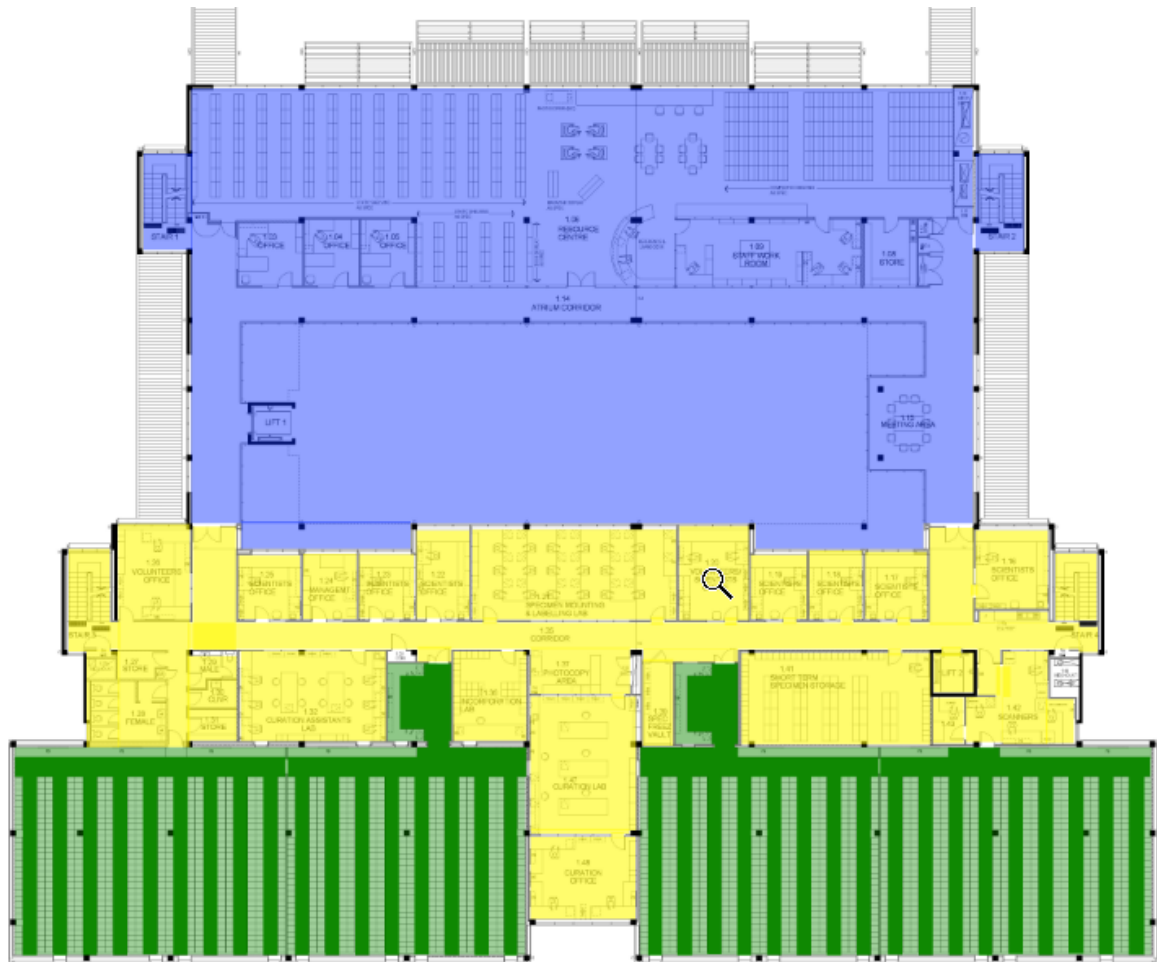
Maintaining physical barriers minimises movement of pests into the building and between rooms. Doors into the building and quarantine areas must remain closed at all times and are not to be propped open. These doors include the exit to the outside, electronic security doors, emergency exits, fire doors, the doors leading to vestibules, vaults (including loans and type rooms) and the Short Term Specimen Store and the doors leading from the specimen preparation areas. Doors to other areas such as offices should be closed at the end of each day and remain closed when staff are on holiday.

Appendix 1: IPM zones in the Keiran McNamara Conservation Science Centre.

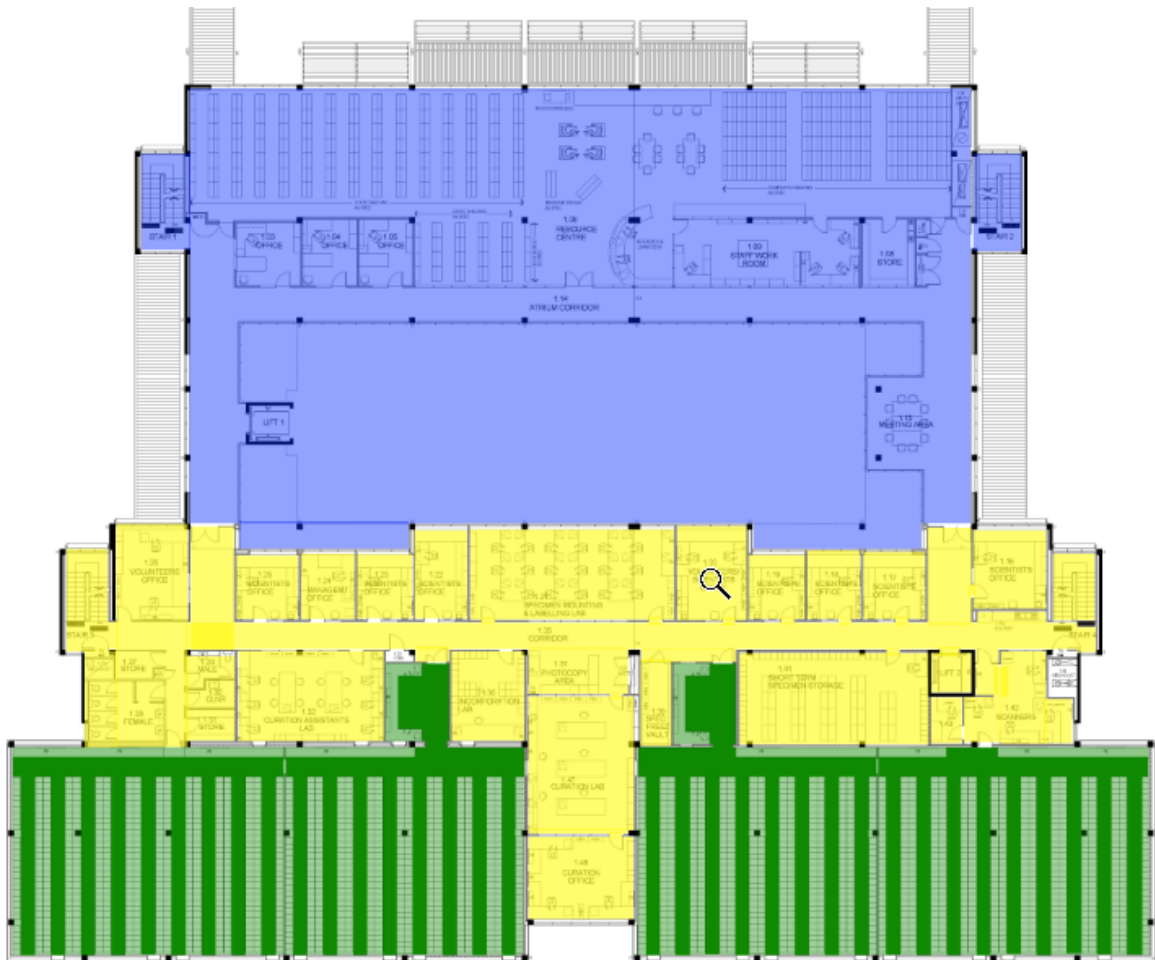
Green zone (high security). No specimens or plant material may enter and be exposed in this zone (on benches, workspaces, and in storage) unless it has been frozen. Unfrozen material may only enter this zone in a snap-lock bag which must remain sealed at all times and may not be stored in the zone.

Yellow zone (medium security). Specimens that have previously been frozen (e.g. specimens removed from the vaults or short term specimen store) may be stored in this zone for short periods (days to weeks) while they are being actively worked on, but should not be kept for longer periods. Unfrozen material may only enter this zone in a snap-lock bag which must remain sealed at all times and may not be stored in the zone.

Blue zone (low security). No herbarium specimens may be stored in offices and labs in this zone. Other dried plant material which may harbour herbarium pests, if stored for more than three weeks, must be sealed in airtight and insect-proof containers. Unfrozen, fresh or dried plant material may be exposed in this zone while being processed, but should be disposed of as soon as possible. Other materials that may harbour herbarium pests (e.g. dirty camping gear) should not be stored permanently in the zone. Living plants and fresh flowers may be kept in offices, but not dried flower arrangements.



KMCS First Floor IPM zones



KMCS Second Floor IPM zones

Appendix 2: Susceptible plant families

All plant specimens are susceptible to damage by insect pests but some are more susceptible than others. The following list of highly susceptible families has been compiled from past pest infestations at PERTH and other Australasian Herbaria and literature references.

Family	Vault number	Family	Vault number
Amaranthaceae	4	Fabaceae	2
Amaryllidaceae	1	Goodeniaceae	4
Apiaceae	4	Lamiaceae	4
Apocynaceae	4	Malvaceae	4
Araceae	1	Moringaceae	4
Araliaceae	4	Myrtaceae (webbing caterpillar)	3
Asparagaceae	1	Nymphaeaceae	1
Asteraceae	4	Orchidaceae	1
Boryaceae	1	Papaveraceae	1
Brassicaceae	4	Proteaceae	1/2
Campanulaceae	4	Ranunculaceae	1
Caprifoliaceae	4	Rosaceae	3
Chenopodiaceae	4	Rutaceae	3
Colchicaceae	1	Scrophulariaceae	4
Convolvulaceae	4	Smilacaceae	1
Dasypogonaceae	1	Solanaceae	4
		Tropaeolaceae	3
		Xanthorrhoeaceae	1

Information collated from:

- Metsgar DA, Byers SC (1999) *Managing the Modern Herbarium* (Elton - Wolf Publishing: Canada)
- PERTH's *Pest Damage Database* (from 1996 to the present).

Appendix 3: Common Pests of the Collection

Tobacco Beetle, Cigarette Beetle (*Lasioderma serricorne*)

The herbarium beetle is the most serious pest in a herbarium due to the rate of generational development. It will attack virtually any product made from plant or animal material including stored food, pyrethrum powder (an insecticide), rodent baits, books and rodent droppings. Herbarium beetles will destroy pressed plant specimens. Most damage is done by the larvae but adults can do further damage via emergence holes.

Lasioderma are differentiated from *Stegobium* by the adult and larvae being smaller, lacking grooves on wing covers, and having uniform filament antennae of 11 segments.

Adult beetles are 2-3 mm long and live 3-4 weeks and females lay up to 100 eggs on the food source, which hatch in 6-10 days. The larvae feed for 5-10 weeks depending on temperature, humidity and available food. Pupation last 2-3 weeks and adults remain in the cocoon until sexually mature. The generation time from egg to reproducing adult is about 2 to 3 months and there can be 5 to 6 generations per year. Adults are strong fliers, fly at night and are attracted to dim light. Indicators of activity include emergence holes of adults, frass or fine dust around food items, adults seen flying or captured in zappers or dead on window sills.

The most important control measure is to find the source of the infestation and remove or destroy the infested material. Tight quarantine procedures (including freezing all incoming specimens), sanitation (cleaning regularly storing food stuffs in insect proof containers) and monitoring (blunder and zapper traps) are the keys to good herbarium beetle control. Sticky pheromone traps can be used to locate the infestation site. Infested specimens are frozen at -18°C for seven consecutive days. Residual sprays can be applied to cracks and crevices where the beetles hide. Insect growth regulators have been shown to be effective in controlling herbarium beetle populations in herbarium collections; fumigation with Methyl Bromide or like gases is effective.



Adult Herbarium Beetle - adult
Image sourced from: www.ozanimals.com



Herbarium Beetle - larvae
Imaged sourced from: www.ozanimals.com

Herbarium Beetle, Drugstore Beetle (*Stegobium paniceum*)

The drugstore beetle attacks a wide variety of foods (flours, dry mixes, breads, biscuits, chocolates and other sweets, and spices) and material (wool, hair, leather, herbarium specimens). They are known to bore through plastic, foil and lead sheets to get to the food source. Most damage is done by the larvae but adults can do further damage via emergence holes.

Stegobium are differentiated from *Lasioderma* by the adult and larvae being larger, having longitudinal grooves on wing covers, and clubbed antennae with 3 elongated and broadened segments.

Adult beetles are 2-3 mm long and live 1-4 weeks and females lay up to 75 eggs on the food source which hatch in a few days. Larvae feed for 16-20 weeks depending on temperature, humidity and available food. Pupation lasts 2-3 weeks and adults remain in the cocoon until sexually mature. The generation time from egg to reproducing adult is about 3-7 months and there can be 1-4 generations per year. Adults are strong fliers, fly at night and are attracted to dim light. Indicators of activity include emergence holes of adults, frass or fine dust around food items, adults seen flying or captured in zappers or dead on window sills.

The most important control measure is to find the source of the infestation and remove or destroy the infested material. Tight quarantine procedures (including freezing all incoming specimens), sanitation (cleaning regularly, storing food stuffs in insect proof containers) and monitoring (blunder and zappers) are the keys to good herbarium beetle control. Sticky pheromone traps can be used to locate the infestation site.

Infested specimens are frozen at -18°C for seven consecutive days. Residual sprays can be applied to cracks and crevices where the beetles hide. Insect growth regulators have been shown to be effective in controlling herbarium beetle populations in herbarium collections; fumigation with Methyl Bromide or like gases is effective.



Drugstore Beetle – adult

Imaged sourced from: www.ozanimals.com



Drugstore Beetle – larvae

Imaged sourced from: www.ozanimals.com

Psocids, booklice (*Liposcelis bostrychophila* and *L. entomophila*)

Psocids may be found on herbarium specimens, paper goods, in books and book bindings and storage boxes. Psocids feed mainly on surface moulds but they also eat damp or mouldy paper and glues. Damage of herbarium specimens is usually confined to delicate flowers and has been reported in Asteraceae, Brassicaceae, petaloid monocots and Campanulaceae; psocids also eat pollen.

Psocids are tiny (1-2 mm long) termite-like insects with chewing mouth parts which thrive under warm, moist conditions. They are extremely difficult to control using chemicals and show high levels of tolerance to fumigants. Under favourable conditions, psocids multiply rapidly with a lifecycle of 21 days, live for 3 months, and lay an average of 20 eggs. For each species there is a critical relative humidity below which they lose water to the environment and eventually die from desiccation – between 50-60% RH. Psocids are typically found in areas of high RH, which is also required for the growth of mould, their primary food. An indication of activity is a fine powder scattered around pockmarked, scarified, damaged/eaten plants or mounts.

Control is by maintaining low dust levels and general good hygiene (psocids feed on dead insects). Freezing of all products entering areas where books and herbarium specimens are kept is effective. Psocid control is best achieved by controlling humidity at or below 50% RH.

Psocids can be monitored by placing a fresh mushroom on paper in the collection as bait overnight. The next morning if psocids are present they may be obvious on the paper and mushrooms.



Psocid: *Liposcelis bostrychophila*

Image sourced from: www.eol.org

Varied Carpet Beetle (*Anthrenus verbasci*)

Carpet beetles are free-living in the environment and are drawn to buildings by lights and the presence of food. Although carpet beetles can fly, they are often brought into buildings as larvae in infested grocery products and packaging materials. Adult beetles may also be brought into buildings on cut flowers since pollen is a favourite food.

The varied carpet beetle has an unusual life cycle for an insect as they can take 1-3 years to develop from larvae into an adult depending on the environmental conditions. The beetle lays 40 eggs (not necessarily on larval food material) and as the larvae are quite mobile, if left unchecked they can quickly spread to other susceptible materials. The adult is ca. 3 mm long and the dorsal surface has scales of two colours, whitish and yellowish-brown. Larvae are 4-5 mm long and the body is covered in a pattern of alternating light and dark-brown stripes.

Larvae feed on animal fibres such as wool, silk, furs, feathers, dead insects and stored food products. Varied carpet beetles have been reported to directly damage herbarium specimens, feeding on seeds and pollen, especially in members of the Asteraceae. The larvae live and feed inside the products, and can be unknowingly moved from room to room in the building. Often the first indication that a building is infested is adults found along window sills or trapped in zappers, as adults are attracted to light. Other signs include the presence of damaged articles and moulted larval skins

Sanitation, inspection and trapping (zappers) are the keys to good carpet beetle control. Freeze incoming specimens and packaging materials, remove spilled food daily, clean and vacuum appropriately, especially along walls where beetles and food products tend to accumulate, store infestible material in containers with tight fitting lids.

Place infested products in a freezer at -18°C for seven consecutive days to kill adults, larvae, and eggs, or fumigation with Methyl Bromide or like gases is effective.



Varied Carpet Beetle – adult
Image sourced from: www.ozanimals.com



Varied Carpet Beetle – larva
Image sourced from: www.ozanimals.com

Other pests of the Herbarium

Portuguese millipedes (*Ommatoiulus moreletii*)

Portuguese millipedes are not a primary pest to herbarium collections; however, dead millipedes present a food source that attracts other serious herbarium pests.

Portuguese millipedes are 20-45 mm long with 50 body segments when fully developed. Adults range in colour from slate-grey to black. Juveniles are light grey/brown, often with a darker stripe along each side. Millipedes normally live outdoors in low numbers but congregate in large numbers after the first rains in autumn. Millipedes do not breed inside buildings, and once inside usually die.

Portuguese millipedes are attracted to lights. External lights close to the building should be turned off, and light escaping from buildings minimised by the use of curtains. If used in conjunction with physical barriers such as weather-strips and smooth barriers, light reduction will prevent the entry of these pests. Millipedes breed and live in moist litter and reducing the area covered by organic matter within 100 m of the building will reduce invasion.

Chemical control of millipedes entering the building is a consideration, but they have a limited active life. Chemical controls can be applied to outside walls and paths. At the old Herbarium when the millipedes were migrating into the building in large numbers, baiting the outside perimeter with grasshopper killer proved extremely effective.



Portuguese millipede

Image sourced from: www.museumvictoria.com.au

Cockroach (*Periplaneta americana* or *Blattella germanica*).

Cockroaches do little direct damage to herbarium specimens. Faecal or regurgitated material can stain specimens making them unsightly; the acidity of the material can continue to damage the paper leading to holes.

Cockroaches are nocturnal and prefer moist warm areas. They are often associated with catering areas and inhabit wall cavities, heating ducts etc.

Sanitation is the key to good cockroach control: emptying bins, cleaning food preparation areas, removing spilled food on a daily basis, and storing foodstuffs in

insect proof containers. Trapping and monitoring can be successful using blunder traps. For small infestations or seasonal use, commercially bought baits are particularly effective when placed near harbourages. The help of a pest control specialist will be needed for their eradication should numbers escalate.

	
<p>American cockroach (<i>Periplaneta americana</i>)</p> <p>Image sourced from: www.ozanimals.com</p>	<p>German Cockroach (<i>Blattella germanica</i>)</p> <p>Image sourced from: www.ento.psu.edu</p>

Ants

Ants cause considerable nuisance if they invade herbaria in numbers but they seldom damage specimens. Ants have nested in boxes of specimens at the old building.

Non-insect pests of Herbaria.

Rodents.

Mice or rats have been known to use using herbarium specimens for nest material and (occasionally) chew into cabinets. Droppings are attractive as a source of food for other pests. When given access to food and undisturbed areas, rodents will breed rapidly. Their presence is evidenced by profuse droppings, gnaw marks, or shredded paper and textiles. Continued baiting of the building is recommended.

Caterpillar (moth unknown)

Eucalypts are susceptible to a leaf rolling caterpillar at the Herbarium, both genus/species of the pest is unknown. It has occurred sporadically in the collection in relatively small numbers, though not in the last few years. It seems not suited to consuming herbarium specimens as it dies whilst still young and doesn't pupate. Evidence of activity is usually frass caught in the webbing used to roll the leaf.

Appendix 4: What to do if a pest is located

Because of the sensitivity of herbarium collections to insect damage, the action and reporting level for most pests is one live pest. Presence of live adults or larvae indicates infestations that should be investigated immediately and treated as necessary. Shed larval skins and feeding damage may have resulted from old infestations, but in regularly monitored collections, these should be regarded as an indication of an active infestation. Thus, it is vitally important to maintain careful monitoring records.

Immediately inform Collections Manager of an observed live pest or evidence of pest activity. Do not proceed with cleaning specimens, office area or disposing of material without first seeking advice from the Collections Manager.

When a pest is detected in a vault (including loans and type room).

When a pest infestation is detected on a specimen:

- determine the extent of the infestation by checking specimens in boxes above, below and adjacent to the outbreak
- minimise the time a box is kept open, particularly if there are adult beetles present, to avoid them escaping and potentially infesting other areas of the Collection
- immediately close a box once an infestation is detected and move the box to the Accessions Preparation Laboratory for further inspection
- confirm the identification of the insect
- determine the course of action
- freeze the infested material in its associated PERTH box at -18° C for 7 days
- clean the specimens and associated PERTH box (refer to the Cleaning Specimens guidelines below)
- record infestation into *Pest Damage Database*
- Collections Manager provides a brief report to the Curator

When a pest is detected elsewhere in a vault (e.g. crawling on the floor or caught in a zapper or blunder trap) check susceptible families in the vault for pest activity (refer to Appendix 2 which lists susceptible families). Record non-specimen based pest detections into the *Pest Monitoring Database*. If pest activity is located, follow the instructions outlined above.

If the activity cannot be located and pests are trapped in subsequent weeks, appropriate pheromone traps will be placed in a grid to help identify the area of infestation.

Zappers will be checked daily until infestation is considered eradicated.

If the infestation continues and is unable to be located, all PERTH boxes containing specimens in the affected vault and ancillary vestibule will be removed and frozen for a period of seven consecutive days at -18° C.

When a pest is detected elsewhere in the building (not in a vault).

When a pest infestation is detected on a specimen:

- determine the extent of the infestation by checking specimens in boxes above, below and adjacent to the outbreak, or if in an office check every specimen
- minimise the time a box is kept open, particularly if there are adult beetles present, to avoid them escaping and potentially infesting other areas of the Collection
- immediately close a PERTH box once an infestation is detected and move the box to the Accessions Preparation Laboratory for further inspection. In the case of a cardboard box, immediately wrap in a plastic bag prior transporting to the Laboratory.
- confirm the identification of the insect
- determine the course of action
- freeze the infested material in its associated box at -18° C for 7 consecutive days
- clean the specimens and associated PERTH box (refer to the Cleaning Specimens guidelines below)
- record infestation into *Pest Damage Database*
- Collections Manager provides a brief report to the Curator

When a pest is detected other than on a specimen, (e.g. crawling on the floor or caught in a zapper or blunder trap), check specimens in the area for pest activity. Record non-specimen based pest detections into the *Pest Monitoring Database*. If pest activity is located on a specimen, follow the instructions outlined above.

In the case of an office, regardless of where the pest was located or the extent of the activity, all specimens will be frozen and the office cleaned.

In the case of the short term storage area, if the activity is unable to be located all specimens will be frozen and the area cleaned.

Zappers will be checked daily until infestation is considered eradicated.

Cleaning Specimens

Once specimens have been frozen, assess the material and document any damage to the specimens:

- examine each specimen and assess the level of damage to the sheet (minor/moderate/severe) and whether the damage is to the flowers, fruits, stems or leaves
- add this information to Pest Damage Database

- add a dated 'Insect activity recorded' slip to the specimen
- clean frass from the sheet
- return specimens to a cleaned box
- freeze the box and contents for seven consecutive days and re-shelve

Treatments

- Thoroughly check and clean the inside of each box frozen to remove any dead insects. Place dead insects and fragmented plant material into a snap-lock bag and discard in a MediCollect bin.
- Vacuum the affected area (eg, entire office or short term storage area) – empty vacuum cleaner in a MediCollect bin and wipe inside of the cleaner prior to re-entering the building
- Wipe down the table and vacuum the curation area where the box and specimens were cleaned.

Appendix 5: Herbarium Cleaning Schedule and Guidelines

Daily: sweep & damp-mop floor (except freezers), empty bins, damp-dust all surfaces (but not the window sills), clean basins

Quarterly: damp-dust grilles (in doors, air ducts, diffusers, vents). Sweep, mop and machine buff herbarium vaults.

Half yearly: Scientists' offices on the Herbarium side of the KMCSC will be emptied of plant specimens every 6 months (at the time of mass freezing for insect control). An attentive clean is required at this time.

During cleaning the contractor shall ensure that the security of the premises is maintained and doors are operated as they are found at all stages of the cleaning process. It is imperative that this practise is adhered to for security and pest management control issues. Particular care must be taken when entering the Herbarium vaults via the vestibule (i.e. the vestibule door must be closed prior to opening the Herbarium vault).