GOVERNMENT OF WESTERN AUSTRALIA

Department of **Biodiversity, Conservation and Attractions**

Western Australian Herbarium

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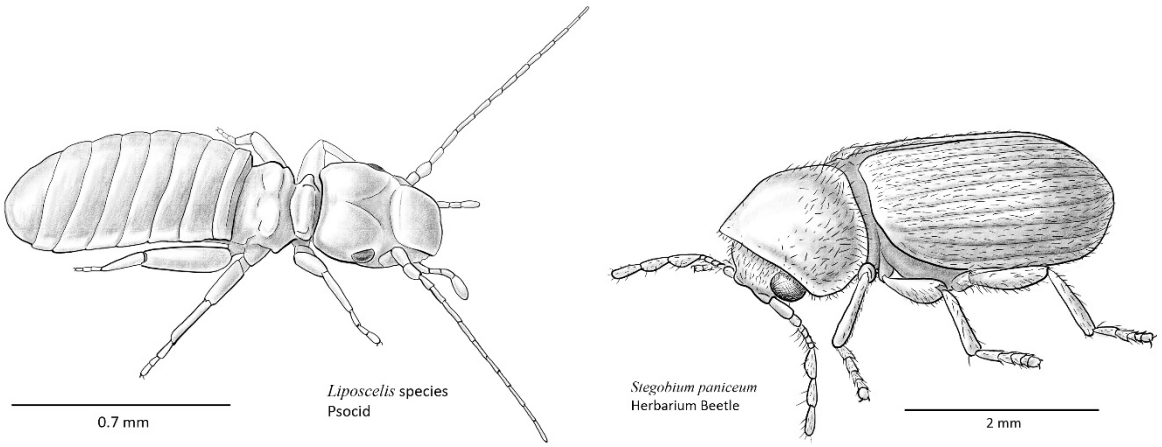
Integrated Pest Management Plan



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

The Western Australian Herbarium acknowledges the Traditional Owners of the land and waters from where our collections have come, and pays respect to their Elders past, present and emerging.

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This Integrated Pest Management (IPM) Plan has been prepared by Karina Knight, Kevin Thiele, Cheryl Parker, and Shelley James, current and former staff of the Western Australian Herbarium.

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 National Herbarium of New South Wales (NSW) kindly provided copies of the NSW IPM Plan. Illustrations on the cover are provided by Lesley Elkin, National Herbarium of NSW, Botanic Gardens and Domain Trust.

This plan will be reviewed and updated annually.

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

Summary

The Integrated Pest Management Plan establishes principles and practices for the handling of plant and paper materials, and other items, that may harbour or encourage insect pests in the Keiran McNamara Conservation Science Centre (KMCSC) which houses the collections of the Western Australian Herbarium (PERTH). Insect pests and microbes (mould) are some of the most severe risks to the safety and security of the Herbarium's specimens and those under the care of the Herbarium. Adhering to this Plan will minimise the risk of damage to this irreplaceable and invaluable State asset.

This 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 three designated IPM zones in the building, and an outline of staff, volunteer and visitor responsibilities and duties under the Plan. Appendices provide summary information on principal insect pest species and their identification and biology, susceptible plant families, and instructions for what to do if an insect pest or mould is located or an outbreak suspected.

It is important that all 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 Department of Biodiversity, Conservation and Attractions Biodiversity and Conservation Science policy by the Division's Science Management Team.

Introduction

Under Western Australian legislation (Conservation and Land Management Act 1984), the Western Australian Herbarium is responsible for the permanent preservation, maintenance, extension, and 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 and invaluable State asset, and underpins biodiversity and 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. Pests are defined here as vertebrate, invertebrate, or microbial organisms that harm or destroy plant specimens and/or the archival materials they are housed with.

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 damage to the Western Australian Herbarium collections.

IPM allows staff working with the collection to be proactive rather than reactive to pest control. The cost of managing pests post-incursion is costly in terms of monetary outlay and staff time, and results in irreparable damage to State asset.

Ideally, the focus of IPM 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, humans, and the environment as it aims to prevent insect outbreaks, microbial growth, and controlled, as needed with a minimal use of pesticides.

Insect pests that damage herbarium specimens are inherently and regularly found within KMCSC, herbarium facilities, and the collection. Serious outbreaks through time have resulted in total or partial loss of some specimens. Some plant taxa are more attractive and susceptible than others (Appendix 1).

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 (see Appendix 2 for scientific names and further information) and others pose direct threats to specimens and humans through feeding damage, faeces, and excretions. Moulds impact the scientific quality of specimens, and pose serious health risks. Other pests pose indirect risks such as fires (rodents gnawing on wires) and secondary infestations (e.g., dead animals and insects attract other pests).

The IPM strategy described in this document applies to the entire KMCSC building, although with greater levels of management in the Quarantine Zone and Reference Herbarium areas, including the vaults and vestibules, offices and laboratories on the south side of the building.

All queries regarding the Integrated Pest Management Plan and conditions affecting the safety and well-being of the collection should be directed to the Collections Manager, herbarium@dbca.wa.gov.au, Phone: 9219 9130.

The Integrated Pest Management Plan

Limiting the breeding of vertebrate and invertebrate (insect) pests in a herbarium collection depends on an integrated approach ensuring that food is limited and environmental conditions are unfavourable for growth and reproduction. For microbes, and particularly moulds, control of relative humidity is critical for the prevention of growth on specimens. Other microbes, such as bacteria and algae, are not as common in regulated collections environments.

A regular building maintenance and cleaning program in all areas of the building enhances the effectiveness of Integrated Pest Management (IPM). 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. While mould, algae and bacteria are inherent in and on all plant specimens and archival materials, proper preparation of specimens is critical for preventing mold outbreaks, along with appropriate storage to minimize water intrusion.

The success of any integrated approach to pest management is to ensure that staff, contractors, volunteers, and visitors 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 insect pests. Active use and observation of the collection is the best method for detection.

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, on personal belongings, or through open doors. 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 prevent insect pests from breeding and completing their life cycle. The environmental conditions of the specimen and archival supplies storage areas in the Herbarium (Vaults, Short-term Specimen Stores, Curation 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). Maintaining environmental conditions at 45% relative humidity prevents the growth of moulds.

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. Excessive human access to collections in storage and quarantine areas, and failure to observe quarantine procedures, are the greatest cause of insect 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 extent of damage that can result from a pest outbreak. 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 and visitors 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 pose a risk to humans and the environment.
- The effect of chemicals on the collection for future scientific use is largely unknown.

Other gaseous treatment, such as CO_2 fumigation or other inert gases, pose other risks to humans and are costly.

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

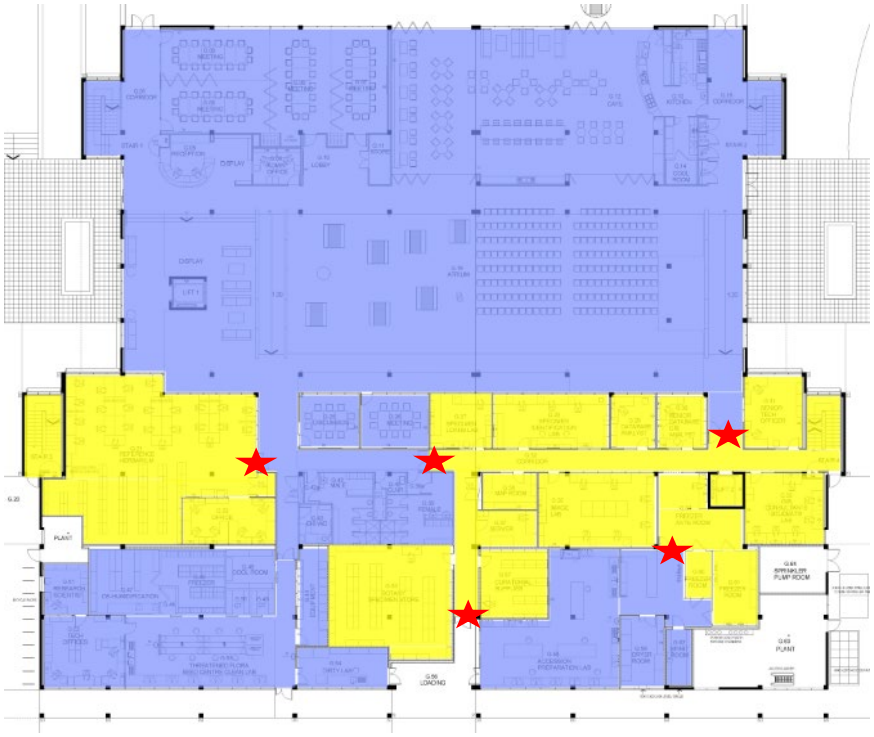
The IPM strategy is reviewed annually by the Collections Manager and Curator, updated or modified as required, and changes communicated to users of the facility as appropriate.

IPM areas and the Quarantine Zone

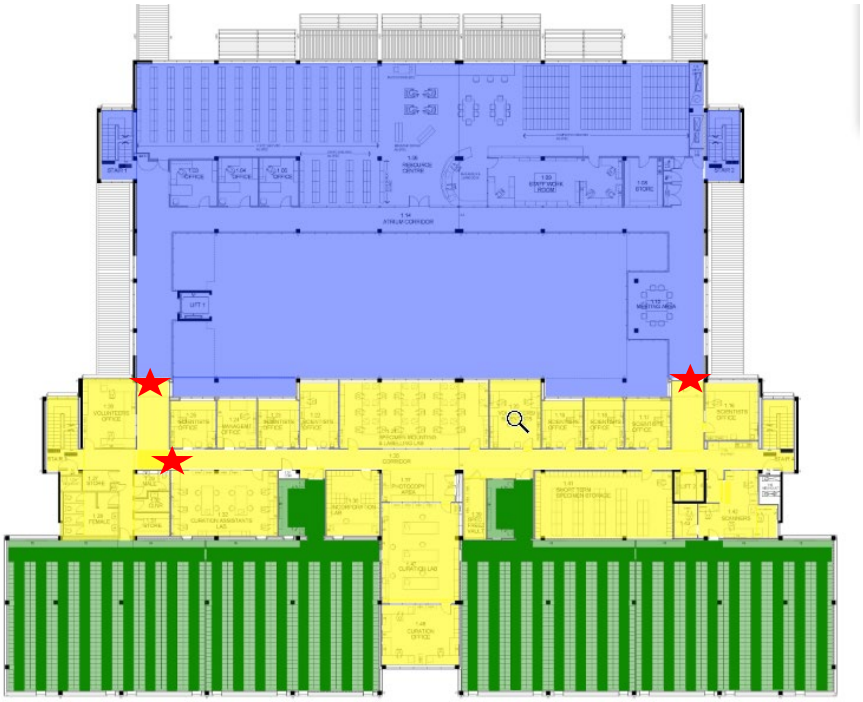
The KMCSC is zoned into areas where different levels of Integrated Pest Management apply. The southern (Western Australian Herbarium) wing of KMCSC has areas designated with having higher risk quarantine areas ("Quarantine Zone" and Reference Herbarium) and have extra swipe-card security and stricter protocols for pest protection. Quarantine Zones are marked with yellow signage on entry/exit doors (red stars on maps below). Outbreaks in these areas are more serious, difficult to control, and can result in the destruction of the irreplaceable and invaluable collections of the Western Australian Herbarium, and collections under the care of the Herbarium. Areas are rated according to the risk of loss of State asset due to pest infestation.

Blue areas (low risk)

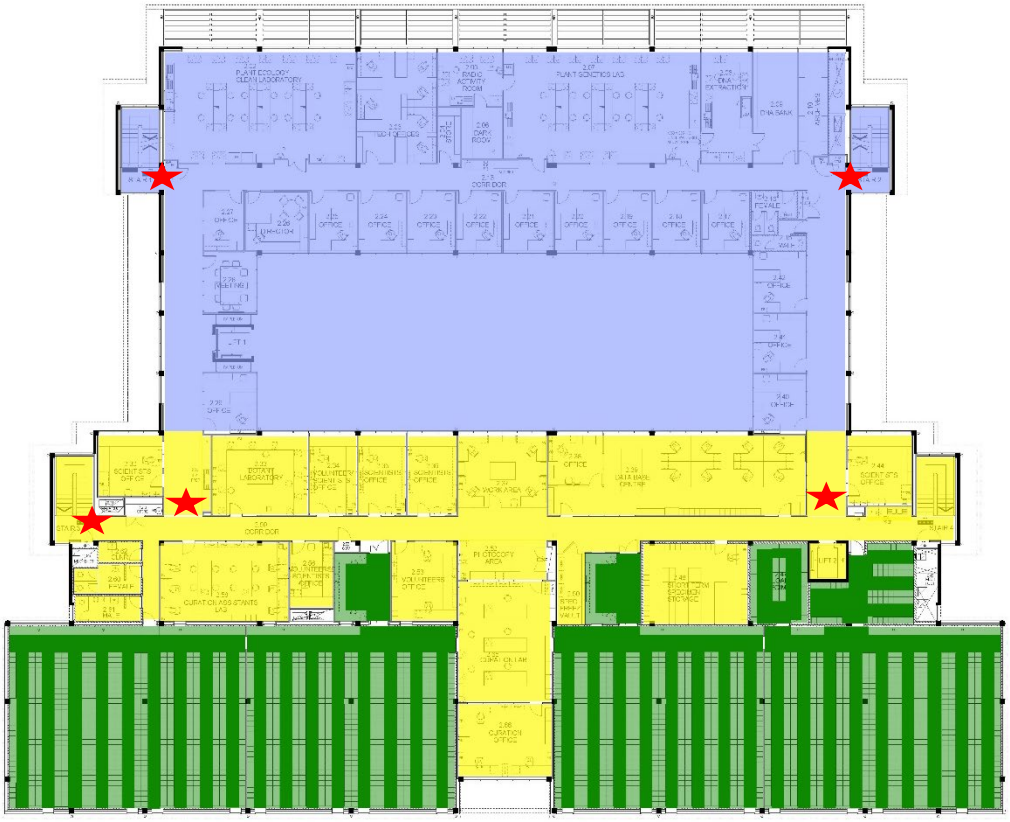
The Blue areas include the Reception, northern wing of the KMCSC building Levels Ground and 1, and preparation areas of the Herbarium and Threatened Seed Centre. No herbarium specimens or other dried plant materials are to be stored in offices and laboratories in this zone. Unfrozen, fresh, and dried plant material may be exposed in this zone, but such material should be disposed of or stored appropriately to avoid the attraction or breeding of pests. While not recommended, living plants and newly-fresh flowers may be kept in offices in the northern wing on Levels Ground and 1 and monitored for insect and/or mould activity. Dried flower arrangements must not be stored in the blue areas. Pest activity is monitored, and restrictions may apply if activity is noted to increase within the Quarantine Zone.



KMCSC Ground Floor IPM areas



KMCSC First Floor IPM areas



KMCSC Second Floor IPM areas

Yellow areas (medium risk)

Yellow areas occur in the Quarantine Zone of KMCSC, Levels Ground, 1 and 2, and including the Reference Herbarium. Specimens that have previously been frozen (e.g., specimens removed from the vaults or Short-term Specimen Stores) may be stored in these areas 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 these areas in a snap-lock bag which must remain sealed at all times and may not be stored. No specimens are to remain exposed in yellow areas (i.e., left on benches, workspaces, and in storage without being in a storage box), especially overnight. Items used in field work must not be stored in yellow areas. Books and paperwork from outside the facility should be fumigated or frozen prior to long-term storage. Frozen corrugated carboard is to be minimized within the area. Food and beverage items must be kept in sealed containers, and food preparation areas remain clean. Food scraps must remain within kitchenette areas.

Green area (high risk)

Green areas occur in the Quarantine Zone of KMCSC, Levels 1 and 2. No specimens or plant material may enter and be freely handled unless it has been frozen for 7 days at <-18°C. Unfrozen material may only enter green areas in a sealed snap-lock bag which must remain sealed at all times and may not be stored in the area. No

specimens are to remain exposed in this area (i.e., left on benches, workspaces, and in storage without being in a storage box), especially overnight. Items used in field work must not enter this area, but may be stored in the Preparation Laboratory. No bags, food, or beverage items allowed. Minimal frozen carboard allowed, but must be stored in a plastic bag to reduce pest and moisture risk.

Please note: Human movement and activity, including the opening of doors, is one of the largest causes of pest movement and infestation within natural history collections. It is requested that unnecessary entry/exit via the Quarantine Zone be avoided at all times. Examples of this might include entry via the South entry as a short-cut to the café or Reception, using emergency exits on Ground Level, entry into the Quarantine Zone to access kitchenette facilities when similar facilities are available in adjacent blue areas, or using stair wells in the Quarantine Zone rather than using those in the blue areas.

Procedures for IPM areas

Green areas

Green areas include specimen storage vaults (vaults 1-4), type and loans vaults, and ancillary rooms (vestibules). No food, beverages, or bags are allowed in green areas. The following IPM procedures apply in these areas.

Movement into the vestibule from the corridor
Specimens, cardboard boxes, PERTH box, loans box, corrugated cardboards, field journals, and paperwork potentially infested 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 cardboard supports must be exchanged outside the vestibule door for red plastic trays.
- Trolleys must be clean and cleared of any obvious debris.
- No personal bags allowed in vaults or vestibules. Storage is provided.

Movement between a vestibule and its associated vault
Vestibules are considered annexes of their vault. Free movement of previously frozen specimens, cardboard boxes, and books between the vestibule and its associated vault is allowed without further freezing unless the following applies:

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

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

Any materials exiting the vestibule must undergo quarantine freezing prior to reentry, regardless of previous freezing actions.

Red PERTH boxes
PERTH boxes are pest and water resistant and provide an important physical barrier to 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 Stores) where pests are more likely to be present. Keeping the lid of the PERTH box closed is the simplest way to avoid damage to specimens.

Yellow areas

Yellow areas consist of general work areas such as the Reference Herbarium, offices and laboratories, Short-term Specimen Stores, and corridors within the Herbarium. With the exception of the Reference Herbarium, food and beverages may be consumed with appropriate sanitation, and stored in sealed containers. The following procedures apply in these areas:

Offices/Laboratories

- Maintain a minimum number of specimens in your office (i.e., those being currently studied).
- Store the remaining material in the Short-term Specimen Store (maintained at cooler and drier environmental conditions).
- Store specimens overnight in Short-term Specimen Stores, where practicable.
- Securely close PERTH boxes that are not in immediate use.

Once every six months, Collections Staff organise to have offices and laboratories attentively cleaned and all plant material stored in offices must be moved to the freezers for a minimum of 48 hours at <-18°C. A minimum notice of two weeks will be given of the impending freeze, to allow staff to prepare for the rotation.

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 areas without requiring further freezing. Movement of specimens between floors should, however, be minimized.

Curation Store
This is for the storage of archival materials used in the Herbarium only. No specimens may be stored in this area.

Freezers and Freezer Ante Room
No materials are to be stored in the Freezers without prior consent from the Collections Manager and appropriate labelling. The Western Australian Herbarium is WA Quarantine Registered Premise. Due to Department of Agriculture, Water and

Environment (DAWE) and Department of Primary Industries and Regional Development (DPIRD) quarantine regulations, no materials are to be added to or removed from freezers without previous notification of the Collections staff.

The Freezer Ante Room is not for general storage. Specimens from the freezers are stored in this area until they are returned to room temperature. This includes specimens belonging the Western Australian Herbarium, along with those from institutions and consultants that are under the care of the Western Australian Herbarium.

Reference Herbarium:

- The door to the Reference Herbarium must remain closed at all times.
- All specimens entering the Reference Herbarium must be frozen in the Western Australian Herbarium facilities, or remain within sealed plastic bags.
- No food or beverages allowed.
- Specimens of the Reference Collection must not be removed from the Reference Herbarium.
- Refer to the *Reference Herbarium User Guide* for further specimen quarantine information.

Blue areas

Blue areas include the Herbarium specimen receival areas (including the Preparation Laboratory, Wet Store, and Dryer room), the common areas in the KMCSC building including the atrium space, meeting rooms, and canteen, and offices and laboratory areas on the northern side of the building, Level 1. Food and beverages may be consumed with appropriate sanitation, and stored in sealed containers.

The following procedures apply in these areas:

Preparation Laboratory

The Preparation Laboratory has direct access to the external environment, and is considered a 'dirty' area, holding material for short periods of time that has entered the building unfrozen, and is not yet processed or accessioned.

- Doors must remain closed at all times.
- Specimens must not be left on the benches overnight.
- Fresh specimens must be processed rapidly to avoid insect and mold development.
- Contact information must be attached to all material.

Dryer Room

The Dryer Room is a 'dirty' area, where fresh material is dried prior to accessioning. Due to the warm, moist conditions, It provides an ideal environment for insects and mold to proliferate.

- Doors must remain closed at all times.
- Specimens must not be retained within driers for longer than a month.
- Monitor specimens to ensure mold is not developing, particularly for succulent taxa.

- Driers are cleaned of plant debris every 6 months.
- Contact information must be attached to all material.

Accessioning area
The accessioning area is part of the Preparation Laboratory.

- Dried and prepared specimens must be processed and frozen as soon as possible.
- Specimens arriving from national or international destinations *must not* be opened.

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 complete their life cycle. 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. *Accessioned Herbarium specimens must not be stored in this area*. Presses containing plant specimens should be placed in the Herbarium's Dryer Room or Preparation Laboratory and be handled as per normal Herbarium processes.

Handling of paper and plant material in the KMCSC

To mitigate the spread of pests that are harmful to herbarium specimens, plant and paper materials entering the KMCSC Quarantine Zone and Reference Herbarium must be handled appropriately using the following protocols.

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 Quarantine Zones of the Herbarium.**
- Immediately place the specimen in the Preparation Laboratory for processing.

Plant material *entering the Reference Herbarium* (refer to the *Reference Herbarium User Guide* for further instructions)

- Seal each specimen separately in a snap-lock bag,
  or
- Freeze specimens using the Herbarium freezing service for a minimum of 48 hours at <-18°C.

Plant material *delivered for identification*

- Freeze specimens using the Herbarium freezing service for a minimum of 48 hours at <-18°C.

Plant material *delivered by mail from within Western Australia*
Immediately upon opening of mail containing specimens, the plant material must be either:

- Sealed separately and remain in a snap-lock bag,
  or
- Placed in the Preparation Laboratory for freezing for 7 days at <-18°C.

Plant material *delivered by mail or hand delivery from interstate or international locations*

- Parcels *must not* be opened.
- Freeze for a minimum of 7 consecutive days at <-18°C prior to opening inner packaging.
- Parcels must be frozen within locked and monitored freezer.

Plant material *for lodgement*

- Freeze specimens for a 7 days at <-18°C

Plant material *requiring access to a vault*

- Seal each specimen separately in a snap-lock bag prior to entering the building (from blue area) or vestibule (from yellow area). **Snap-lock bagged specimens must not be opened at any time within the vestibule or vault.**

Plant material *for incorporation into a vault*

- Specimens frozen in freezer on same floor as vault for 7 consecutive days 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 (DPIRD) and accredited to receive and handle plant material. Compliance with DPIRD 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 for incineration. Five MediCollect bins are available at the Herbarium for plant material disposal:

1. Preparation Laboratory – for plant material from anywhere within KMCSC
2. Loan Preparation room (Ground Floor, adjacent to Freezer Anteroom) – plant material from anywhere within Quarantine areas yellow and green on the Ground Floor, including loans packaging.
3. Reference Herbarium – users of the Reference Herbarium are requested to take away their plant material (including those in snap-lock bags), newspapers and boxes; only fragmentary plant material and sweepings may be disposed of in the MediCollect bin.
4. Mounting room – for plant material from within Quarantine areas yellow and green on Level 1.

5. Curation Lab, Level 2 – for plant material from within Quarantine areas yellow and green, including disposal of loans packaging.

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

Fresh material, including food items

- Fresh flowers delivered to any staff within the Quarantine Zone (yellow and green areas) can only be stored in the Preparation Laboratory until collected and removed from the building.
- Fresh plant material used in other areas of the KMCSC, such as the genetics laboratories, should be disposed of carefully as soon as no longer required.
- Living plants (e.g, pot plants) are not permitted in the green and yellow zones.
- Food and beverage items must be disposed of in kitchenette bins only (not left in office bins).
- Cigarettes and other tobacco products must not enter the Quarantine Zone or Reference Herbarium.

Paper products

- All corrugated carboard must be frozen prior to entry into the Quarantine Zone.
- All starch noodles or shredded paper used as packing product must be frozen prior to entry into the Quarantine Zone.
- Products arriving in corrugated cardboard must be unpacked in the Preparation Laboratory and packaging placed in the recycling bin immediately, if not to be frozen.
- Brand new publications and paper products may enter the Quarantine Zone without treatment. Older books and paperwork should be inspected for evidence of book lice and silverfish and treated accordingly.

General building hygiene

Hygiene is one of the most important aspects of a successful 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 staff, volunteers, and visitors in the Quarantine Zone of KMCSC.

Sanitation

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

- Food and liquids must not be taken into the Reference Herbarium, specimen storage areas, vaults, vestibules, or specimen processing rooms.

- After eating or drinking, food scraps, crumbs and sticky food residues on surfaces must be cleaned up.
- Food and beverage items must only be placed in bins associated with kitchenette areas to localize the potential attraction of insect and vertebrate pests.
- Food (e.g., snacks and lunches) and potential insect food items stored in offices must be sealed in plastic or glass, insect-proof containers.
- Food that must be stored for longer periods (e.g., camping stores) should be taken off-site, stored in sealed containers in the Preparation Laboratory, or when on-site, must be kept in a fridge or 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 reused 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 Western Australian Herbarium is regularly reviewed by the Collections Manager and includes an assessment of all rooms in the Quarantine Zone including stairwells and the Reference Herbarium. Refer to Appendix 4 for the Quarantine Zone cleaning schedule.

IPM duties and tasks

The Collections Staff are front-line staff for pest management and control and have prime responsibility for ensuring the safety of the collection. However, all DBCA staff located within the Quarantine Zone in particular, and KMCSC in general, have a duty of care to protect the Western Australian Herbarium collection and botanical specimens. All staff, volunteers, contractors, and visitors should be empowered to consult Collections Staff about any possible breaches of this IPM plan or if insect outbreaks are noticed or suspected.

Monitoring using traps

Electronic Insect Killers ('Zappers') emit ultraviolet light (black light) that attracts flying insects, particularly beetles, flies, and moths. Insects are drawn into the trap, electrocuted and fall to a shelf which is checked periodically and insect species and number documented. The traps are checked and emptied regularly as the dead insects themselves attract beetles and other scavengers. Zappers are on timers, operate between 6pm and 6am, and are checked monthly in the green areas (vaults and vestibules), and every two weeks within all other areas of the Quarantine Zone and Reference Herbarium.

Blunder traps are large sticky traps that catch crawling insect and vertebrate pests. They are placed on the floor just inside doorways against a wall, capturing pests

entering or leaving the room. Capture rate will indicate if there is an issue with pest incursion 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. They are not recommended if an outbreak is not evident as they also attract pests into an area. The Western Australian Herbarium does not currently use pheromone traps.

Inspection

Systematic visual inspection of specimens is not a routine task in the climate-controlled specimen vaults and other work areas unless pests are detected in the traps. However, use of the collections and curation activities allow for incidental inspection of pest activity. If an outbreak is detected by zapper and blunder traps, known susceptible families will be checked randomly in the adjacent area (families to check are listed in Appendix 1, *Susceptible Plant Families*), and the surrounding area.

Indicators of infestation include live adults and larvae, the presence of frass, 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 the small adults, larvae, and eggs if an infestation is suspected.

Visual and regular inspection of all specimen storage areas, laboratories, and offices assess for cleanliness and evidence of pests. Window-sills should be regularly inspected and cleaned at least every six months in the Quarantine Zone 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.

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 DPIRD for identification. Refer to Appendix 2, *Common Pests of Herbarium Collections* for aids to identification, information on biology of the pests, and recommended methods of control.

Record Keeping

Careful records of inspection results and trap catches help identify seasonal risk factors and areas with a high frequency of infestation. 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. 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 or sighted, the date and any other relevant information. Infestations on specimens are treated in the manner outlined in Appendix 3: *What to do if an outbreak is located*.

Maintenance of building and housekeeping

Regular inspection of the KMCSC building is undertaken to ensure physical barriers to pest ingress are maintained and replaced as necessary. Checks include ensuring that doors close properly, insect barriers (door brushes) around doors are fitted correctly and still working, and zappers and timers are working. 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 Stores, and the doors leading from the specimen Preparation Laboratory. Doors to other areas such as offices should be closed at the end of each day and remain closed when staff are on holiday.

All working areas should be kept clean and free of insects, lint, dust, and plant particles that might serve as substrates for insects either directly or indirectly by acting as a growth medium for fungi. Carpets in office areas should be vacuumed and steam cleaned regularly.

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 Stores, Botany Store) are maintained at around 16°C and 45% Relative Humidity (RH). The remainder of the building is maintained at a temperature conducive to humans (and pests). The design of the PERTH boxes also ensures a level of microclimate control. 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 environmental control systems break down. Should environmental conditions vary from the programmed values, the Curator and KMCSC Assets team is alerted.

Appendix 1: Susceptible Plant Families

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

Order	Family	Impacted herbaria	Vault
Fungi	Aphyllophorales; mushrooms	southern African herbaria	1
Pteridophyta	Osumundaceae	southern African herbaria	1
Nymphaeales	Nymphaeaceae	NSW (*Nymphaea*), PERTH, southern African herbaria	1
Alismatales	Araceae	CNS (*Typhonium* - psocids), PERTH, NSW (mould)	1
	Hydrocharitaceae	NSW (mould)	1
	Juncaginaceae	HO (*Cynogeton*)	1
	Potamogetonaceae	NSW (mould)	1
	Ruppiaceae	NSW (mould)	1
Liliales	Colchicaceae	PERTH	1
	Smilacaceae	PERTH	1
	Liliaceae	southern African herbaria	1
Asparagales	Orchidaceae	CANS (carpet beetle), PERTH, southern African herbaria	1
	Boryaceae	PERTH	1
	Asteliaceae	HO (*Milligani*)	1
	lridaceae	CANS (carpet beetle)	1
	Asphodelaceae	NSW (*Bulbine* - Stegobium)	1
	Xanthorrhoeaceae	NSW (*Xanthorrhoea, Lomandra* - Stegobium), PERTH	1
	Amaryllidaceae	PERTH, southern African herbaria	1
	Asparagaceae	PERTH	1

Arecales	Dasypogonaceae	PERTH	1
Zingiberales	Cannaceae	WELT	1
Poales	Bromeliaceae	Marie Selby BG	1
	Juncaceae	CANS (carpet beetle)	1
	Cyperaceae	southern African herbaria	1
	Poaceae	WELT	1
Ranunculales	Papaveraceae	PERTH	1
	Ranunculaceae	WELT, PERTH, NSW	1
Proteales	Proteaceae	PERTH	1-2
Saxifragales	Haloragaceae	NSW (*Haloragis exalata* - Stegobium)	2
Zygophyllales	Zygophyllaceae	NSW (Stegobium)	2
Fabales	'Fabaceae'	CANS *(Acacia, Pultenaea* - carpet beetle), CNS (*Acacia* -psocids), DNA, HO, MEL (some Mimosaceae), NSW (Faboideae: *Swainsona*, *Astragalus*, *Lotus* - Stegobium; psocids), PERTH, southern African herbaria	2
Rosales	Rosaceae	WELT, PERTH, AUA	3
Cucurbitales	Cucurbitaceae	CNS (psocids), WELT, NSW	3
Celastrales	Celastraceae	southern African herbaria	3
Malpighiales	Passifloraceae		3
	Salicaceae	Harvard (A)	3
	Euphorbiaceae	southern African herbaria	3
	Phyllanthaceae	HO (*Phyllanthus*)	3
Myrtales	Onagraceae	WELT (spot checks, *Oenothera*, *Ludwigia*)	3
	Myrtaceae	CANB *(Verticordia* - Lasioderma), WELT, PERTH (webbing caterpillar)	3
Sapindales	Rutaceae	PERTH	3
Malvales	Malvaceae	DNA, NSW, PERTH, southern African herbaria	3

Brassicales	Tropaeolaceae	PERTH	4
	Moringaceae	PERTH	4
	Capparaceae	CNS (psocids), WELT, southern African herbaria	4
	Brassicaceae	CANB (carpet beetle), CNS (psocids), DNA, NSW, WELT, PERTH, US, RSA (cigarette beetle); southern African herbaria	4
Caryophyllales	Amaranthaceae/Chenopodiaceae	CANB (carpet beetle), PERTH	4
	Aizoaceae	southern African herbaria	4
	Cactaceae	FLAS, NSW (mould)	4
Ericales	Ericaceae	NSW?	4
Gentianales	Gentianaceae	southern African herbaria	4
	Apocynaceae	CANB (carpet beetle), NSW, PERTH, southern African herbaria	4
Boraginales	Boraginaceae	WELT	4
Solanales	Convolvulaceae	NSW, PERTH	4
	Solananceae	NSW	4
Lamiales	Scrophulariaceae	NSW, PERTH, southern African herbaria	4
	Pedaliaceae	southern African herbaria	4
	Acanthaceae	NSW, US	4
	Bignoniaceae	SJSU, southern African herbaria	4
	Lamiaceae	PERTH, NSW	4
	Orobanchaceae (*Castilleja*)	SJSU	4
Asterales	Campanulaceae	PERTH	4
	Goodeniaceae	PERTH	4
	Asteraceae	PERTH, NSW, southern African herbaria	4
Dipsacales	Caprifoliaceae	PERTH	4
Apiales	Araliaceae	PERTH, southern African herbaria	4
	Apiaceae	PERTH, WELT, southern African herbaria	4

References:

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Appendix 2: Common Pests of Herbarium Collections

***Lasioderma serricorne* - Tobacco Beetle or Cigarette Beetle**

Lasioderma serricorne is one of the most serious pests 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. *Lasioderma* will destroy pressed plant specimens. Most damage is done by the larvae, but adults can do further damage through the creation of emergence holes.

Adult beetles are 2-3 mm long and live 3-4 weeks. 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, or 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 but have the disadvantage of attracting adults into an area. Infested specimens are twice frozen at <-18˚C for 7 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 *Lasiderma* - adult
Image source: www.ozanimals.com

Lasioderma - larvae
Imaged source: www.ozanimals.com

***Stegobium paniceum* - Herbarium Beetle or Drugstore Beetle**

Stegobium paniceum are a serious pest of herbarium collections, an attack 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 through the creation of emergence holes.

Adult beetles are 2-3 mm long and live 1-4 weeks. 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 but can also attract adults into the area.

Infested specimens are twice frozen at <-18˚C for 7 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.

Stegobium – adult
Imaged source: www.ozanimals.com

Stegobium – larvae
Imaged source: www.ozanimals.com

***Typhaea stercorea* – Hairy Fungus Beetle**

The native *Typhaea sterocorea* is common on traps within the Western Australian Herbarium. As the common name suggests, the hairy fungus beetle is a scavenger that feeds primarily on molds found on pot plants or mould grains and foods. While this species may not be a direct feeder of herbarium specimens, mould infested specimens are a target, and they secondarily provide a food source for other herbarium pests.

Typhaea sterocorea are 2.2–3.0 mm long, brown in color with black eyes, and have hairy elytra with parallel lines of fine hairs. They have slender antennae with the last three segments enlarged. Adults are capable of flight. Mature larvae are whitish to pale brown, 4-4.5 mm long. It takes 21 to 33 days for the species' eggs to hatch

The beetle can be a direct hazard to humans carrying *Salmonella enterica* Serovar Infantis implicated in human foodborne illnesses.

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Beetle identification

The three small beetle taxa (*Lasiodema, Stegobium* and *Typhaea)* are often confused due to their similarity in size, appearance and frequency in herbarium collections. *Lasioderma* are differentiated from *Stegobium* by lacking grooves on wing covers, and having serrated uniform filament antennae of 11 segments. *Stegobium* are differentiated from *Lasioderma* by having longitudinal grooves on wing covers, and clubbed antennae with 3 elongated and broadened segments. *Typhaea* can be differentiated by their slender antennae having the last three segments enlarged.

***Liposcelis bostrychophila* and *L. entomophila* – Psocids or Booklice**

Psocids may be found on herbarium specimens, paper goods, in books and book bindings, and in storage boxes. Psocids feed mainly on surface moulds but they also eat damp or mouldy paper and glues , and other dead insects. 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 between 50-60% RH below which they lose water to the environment and eventually die from desiccation. 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. Freezing of all products entering areas where books and herbarium specimens are kept is effective. Heat treatment has been found to be more effective in some cases, particularly where moisture content in the affected specimens is high. 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 source: www.eol.org

***Anthrenus verbasci* - Varied Carpet Beetle**

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 about 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 various food-source items, 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 7 consecutive days to kill adults, larvae, and eggs. Ffumigation with methyl bromide or similar gases is effective.

Varied Carpet Beetle – adult
Image source: www.ozanimals.com

Varied Carpet Beetle – larva
Image source: www.ozanimals.com

Other pests of the Western Australian Herbarium

***Ommatoiulus moreletii* - Portuguese Millipedes**

Portuguese millipedes are not a primary pest of 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 source: www. museumvictoria.com.au

***Periplaneta americana* or *Blatella germanica* - Cockroach**

Cockroaches do minimal 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, and other enclosed spaces.

Sanitation is the key to good cockroach control: localizing food waste to kitchen areas, 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 high risk areas. Baits are placed in kitchen areas of KMCSC next to refrigerators and under sink cupboards, and replaced regularly. The help of a pest control specialist is needed for their eradication should numbers escalate.

American cockroach (*Periplaneta americana*)
Image source: www.ozanimals.com

German Cockroach (*Blatella germanica*)
Image source: www.ento.psu.edu

Ants cause considerable nuisance if they invade herbaria in numbers, but they seldom directly damage specimens. Ants were previously found to nest in boxes of specimens at the old Herbarium building.

Drosophila (Fruitfly) species are regularly caught in traps in KMCSC, and the species could comprise any one of the 300 or so native or 6 introduced species, but more likely the introduced species. The small flies are attracted to yeast (rotting fruit, etc.), come from sinks, or are brought in with food stuffs. While they are not a direct threat to a Herbarium collection, the insects introduced to the environment become food for herbarium pests.

Sphaerocerid flies Sphaeroceridae is a large family of flies with a worldwide distribution. They are found in diverse habitats and are often encountered in large numbers, typically associated with decaying organic matter such as plants, fungi or faeces, where their larvae feed on microbial material. More than 1300 species of Sphaeroceridae are known worldwide and are currently represented in Australia by 69 species in 29 genera. In KMCSC, they are most likley associated with pot plants.

Anobiidae are native beetle attracted to fresh *Eucalyptus* nuts and come into the Quarantine Zone with fresh material or randomly enter the building from the surrounding gardens. If numbers continue to increase in monitoring traps, they are most likely being introduced into the building through poor quarantine practices. Anobiidae are not a direct threat to the Herbarium collection, but insects introduced to the environment become food for other herbarium pests.

Anthicidae are ant-like beetles that are attracted to fungi and detritus. These are most likely attracted to and/or breeding in pot plants within KMCSC.

Lepisma saccharina **- Silverfish** are not currently an issue within the Western Australian Herbarium, but are a high risk due to their consumption of materials that contain polysaccharides, such starches and dextrin in adhesives. Food sources include herbarium labels, folders and backing papers, book bindings, paper products, dead insects, carpet, and food items.

Adults of the Silverfish are up to 13 mm long when fully grown, the females slightly larger and stouter than the male. The body is wingless, greasy to the touch due to numerous surface scales and hairs, carrot-shaped, tapering to the rear where there are three divergent bristle-like processes; the head with two antennae about as long as the tail processes. The upper surface is silvery-grey, the lower creamy-white. About 50 eggs are laid, in small groups. The eggs are broadly oval and 1.5 x 1.0 mm in size, at first smooth and whitish, changing to yellow then brownish and wrinkled. Incubation takes 43 days at 22°C and 19 days at 32°C. The nymphs are at first minute and scale-less, growing and moulting five to six times to reach adulthood after five to 24 months, depending on available food and temperature.

Silverfish are more common in damp places, and active at night. They can be found in cracks of walls, cupboards, on bookshelves, among undisturbed stored papers, and behind pictures. They can move rapidly and may migrate considerable distances in search of food.

Caterpiller (moth unknown) Eucalypts are susceptible to a leaf rolling caterpillar at the Western Australian Herbarium, both genus/species of the pest is unknown. It has occurred sporadically in the collection in relatively small numbers, though not recently. It seems not suited to consuming herbarium specimens as it dies whilst still young and does not pupate. Evidence of activity is usually frass caught in the webbing used to roll the leaf.

Non-insect pests of Herbaria

Rodents Mice or rats have been known to use using herbarium specimens for nest material and (occasionally) chew into storage units. 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.

Moulds or mildews are fungi that grow on living and dead plants, and some synthetic materials. Moulds are inherently found in outdoor and indoor environments, and on plant specimens. Accumulations of dust can result in mould, and consequently attract pest insects. In well ventilated buildings with

environmental controls and air filtration such as KMCSC, the concentration of mould spores and growth of fungal hyphae is usually not hazardous. Some molds can be infectious to humans, and predisposing health conditions make some people more vulnerable to moulds.

No mould can grow under 60% relative humidity (RH) without ancillary water. Mold infestation may occur on improperly dried herbarium specimens, as a result of water damage, or increased environmental humidity. Succulent specimens, collections wet on pressing, or specimens with sugary exudations or large quantities of nectar are particularly susceptible. Specimens become covered with hyphae and sporangia/conidia, and have a musty smell. Fungal growth can be treated wearing appropriate PPE (gloves, mask or respirator, or using a fume hood), removing spores by brushing and using a vacuum with HEPA filter, and treating with 95% ethanol, drying and freezing. Treatment, however, alters the specimen for chemical or other investigative research and only kills the fungus present on the surface of the specimen. Previously infected specimens are more susceptible to future infestation.

Areas in KMCSC more susceptible to mould growth include kitchenette areas, refrigerators, the Dryer Room, and freezer walls and seals. These are treated with household products as Collections Staff using appropriate PPE as discovered.

Appendix 3: What to do if a pest is located

Because of the sensitivity of herbarium collections to insect and mould 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.

Insect pests

Detection in a vault or vestibule (including loans and type room)
When an insect pest infestation is detected on a specimen:

- Immediately close a box once an infestation is detected and move the box to the Preparation Laboratory for further inspection and preliminary insect identification.
- Minimise the time a box is kept open during inspection, particularly if there are adult beetles present, to avoid them escaping and potentially infesting other areas.
- Determine the extent of the infestation by checking specimens in boxes above, below, and adjacent to the outbreak, and in the row behind and opposite (particularly of the same taxonomic group).
- Freeze all infested material in its associated PERTH box at <-18° C for 7 days
- Confirm the identification of the insect using the services of DPIRD, and if necessary, quarantine the area (zero access).
- Monitor area daily for a period of a week to ensure no further infestation occurs.
- 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, and IPM procedures reviewed.

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 1: *Susceptible Plant Families*). Record non-specimen based pest detections into the *Pest Monitoring Database*.

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

If the infestation continues, the area will be quarantined (zero access) and 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.

Zappers will be checked daily until infestation is considered eradicated.

Detection elsewhere in the building (yellow areas)
When a pest infestation is detected on a specimen:

- Immediately close a PERTH box once an infestation is detected and move the box to the Preparation Laboratory for further inspection and preliminary insect identification. In the case of a cardboard box, immediately wrap in a plastic bag prior transporting to the Laboratory.
- 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.
- 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.
- Confirm the identification of the insect using the services of DPIRD.
- 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, and IPM procedures reviewed.

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 all pest detections into the *Pest Monitoring Database*.

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 Areas, 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.
- In severe cases, the specimen may need to be deaccessioned, or not accessioned in the case of unincorporated material.
- Add information to *Pest Damage Database.*
- Add a dated 'Insect activity recorded' slip to the specimen.
- Carefully clean frass from the sheet using appropriate PPE (i.e., mask or respirator in a well-ventilated area, or in fume hood if possible)
- Return specimens to a cleaned box.
- Freeze the box and contents for a second, seven consecutive day period 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 (e.g., entire office or short-term storage area) with equipment with a HEPA filter – empty vacuum cleaner in a MediCollect bin outside the building, 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.

Mould Infestation

When a mould infestation is detected on a specimen:

- Immediately close the PERTH box once an infestation is detected and move the box to the Preparation Laboratory for further inspection. In the case of a cardboard box, immediately wrap in a plastic bag prior transporting to the Laboratory.
- Minimise the time the box is kept open.
- Determine the extent of the infestation by checking specimens in boxes above, below and adjacent to the outbreak.
- Freeze the infested material in its associated box at <-18° C for 7 consecutive days.
- Treat affected specimens wearing appropriate PPE (gloves, mask or N-95 respirator, or using a fume hood), removing spores by brushing and using a vacuum with HEPA filter, and treating with 95% ethanol, drying and freezing.
- Clean the containing PERTH box with soap and water, and wipe with 70% Ethanol.

- In most cases, the archival backing paper, flimsy, folder may need to be replaced. Treat labels with 95% ethanol.
- In severe cases, the specimen may need to be deaccessioned, or not accessioned in the case of unincorporated material.
- Record infestation into *Pest Damage Database.*
- Collections Manager provides a brief report to the Curator.

Appendix 4: 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: Offices in the Quarantine Zone 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.

General Guidelines

Disposal of plant material

All plant material (including sweepings and contents of a vacuum bag) must be placed in a yellow Quarantine (MediCollect) bin. Quarantine bins are available on each floor of the Western Australian Herbarium and in the Reference Herbarium. No other type of rubbish or wet rubbish is to be placed into this bin, or sweepings from outside the Herbarium.

Cleaners must not empty a general rubbish bin when plant material is located within it. Alert the Collections Manager the following day who will address the issue with staff.

Quarantine Zone

Rubbish and sweepings from outside of the Herbarium (i.e., from the Atrium, top and middle floor on north side of the building) must not be brought into the Herbarium (yellow and green) areas.

Vault/Vestibule (4 areas on top and mid floor)

Green zone areas must not be entered or cleaned by the cleaners except at the Attentive Clean. Ignore rubbish in the bins; this will be addressed by Collections Staff.

Security and Pest Management

The security of the premise must be maintained at all times and doors operated as they are found; it is extremely important that this practise is adhered to for security and pest management control issues. In short:

- Doors into and within the Quarantine Zone must not be propped open at any time.
- Doors into the vestibule and vault areas must not be propped open at any time.
- Doors must be closed at the end of the evening after the clean.

Equipment

- Brooms, mops, dusters, brushes etc. must be kept free of plant debris and fluff to reduce the chance of transferal of insects around the building.
- Vacuum cleaners may only be opened in the Specimen Preparation Laboratory or outside the building to ensure pest do not escape into the building.
- Vacuum bags must be replaced or cleaned regularly to deter pests breeding within.
- Sweepings must not be accumulated in the cleaning cupboard; they must be disposed of at the end of each cleaning session.

Attentive clean Guidelines

The Cleaners will move chairs and other mobile furniture to allow cleaning in areas they do not normally access. Staff will assist by moving their own office furniture into the middle of the room and removing all items from the floor and from up against the walls.

Offices and Work areas:

- Dry dust, skirting and horizontal bench supports.
- Dry dust window-sills (only if clear of 'junk' or able to be reached).
- Vacuum the entire available floor area.
- Mop floors.
- In the Reference Herbarium dust the top of the shelving and all the shelves.

Vault/Vestibule areas (including rooms 1.36, 1.41 and 2.48)**:**
The vacuum bags and filters must be new to avoid transferal of dust into the vault (dust can set off the VESDA fire alarm system). Mop heads and cleaning tools must be new to avoid transferal of insects etc. into the area

- Dry dust the top of the box stacks.
- Dry dust, skirting and horizontal bench supports.
- Dry dust window-sills.
- Vacuum with a brush or hard floor attachment the entire floor area (includes under the racking).
- Spot clean furniture, doors, switches .
- Mop all floor areas (including under the racking).