Occurrence of Pest, the Management of Zoological Museum Specimens Collection and Climate Change

Arney Sapaat[1,2,*] Siti Fatimah Sabran[1,2] Maryati Mohamed[1,2]

[1] *Faculty of Applied Science and Technology (UTHM Pagoh Campus, Pagoh Higher Education Hub, KM 1, Jalan Panchor, 84600, Pagoh, Johor, Malaysia)*
[2] *Centre of Research, Sustainable Uses of Natural Resources (UTHM Pagoh Campus, Pagoh Higher Education Hub, KM 1, Jalan Panchor, 84600, Pagoh, Johor, Malaysia)*
[*]*Corresponding author. Email: arney@uthm.edu.my*

ABSTRACT
This study aims to assess the occurrence of pests of zoological specimen collections at natural history museums, management of the specimens with climate change patterns in Malaysia. The objective of this study was to determine the causes that damaged zoological specimens and the effectiveness of the treatment used. It focused on collection management, a term applied to various methods in which museum specimens are assembled, organized, researched, interpreted, preserved, and narrowed down to identifying and treating pests, the primary agents of natural history collection loss in Malaysia. It is critical to manage collections effectively in order to guarantee that they fulfil the museum's mission. Understanding the relationship between pests and climate change may aid in the preservation of museum artefacts. Twenty-five curators and collection managers from eleven Malaysian institutions were questioned to learn about I their practise of maintaining zoological specimens in natural history collections, (ii) the concerns and challenges their institutions confront, and (iii) risks to their zoological specimens. Because *Aspergillus* sp., *Chaetomium* sp., and *Mucor* sp. are often discovered in natural history collections, their presence in this research is unsurprising. Although the insects observed in this research are often considered household pests, they may become a concern at museums as well. Low temperature and alcohol treatment demonstrated to be the most effective non-pesticidal strategy for zoological collection rehabilitation. To maintain the value of a natural history collection, it must be cared for, conserved, and subjected to ongoing scientific input. While establishing a pest-free environment is difficult, it should be done for the benefit of natural history collections.

Keywords: *Climate change, Museum pests, Pest occurrence, Zoological collection.*

1. INTRODUCTION

Biological entities that can harm museum collections are known as museum pests. Pests are a major threat to museum collections. They may result in catastrophic harm to museum, library, or archive artefacts that are very valuable and irreplaceable. Pests include insects, rodents, bats, birds, and mould. The cumulative consequences of this deterioration might finally result in the destruction of a museum piece. The damage caused by insects, cast skins, or feacal marks is often the first signs of their existence rather than the pest itself. It is critical to keep an eye on collections for signs of pest activity, as most of the natural history collection comprises edible plant material or animal protein that is sensitive to pest assault.

In museums, pest management typically initiated in response to signs of pest activity, such as damage to artefacts or structural components. Because eradicating all pests from a building is seldom achievable, it is vital to deny them a suitable habitat to eat and develop once they are inside. Un Understanding the environment in which pests thrive is crucial to avoid infestations. Humidity is a critical component in developing fungi and insects in general. However, there are significant variances between different fungi and different kinds of insects. For example, silverfish and the wood-boring beetle (*Anobium punctatum*) are good indications of high humidity, whereas clothing moths may exist at low levels of water availability. Many fungi require water with a relative humidity of greater than 75 percent. However, some *Aspergillus* sp. can survive at levels slightly higher than 65 percent.

Controlling probable microclimatic niches is vital to prevent fungal and insect growth: Hot spots of possible humidity might be outer walls, corners and recesses, and compact shelves with minimal ventilation. It is feasible to prevent them from establishing themselves by denying them the four things they require: food, warmth, humidity, and shelter. The four factors are frequently intertwined, and striking the appropriate balance is not always easy. It is also critical to design protocols, such as incoming material quarantine, to ensure that a pest is not introduced due to routine collection activities.

Climate change is defined as changes in the state of a climate that can be quantified (e.g., using statistical tests) by changes in the mean and variability of its features and that persist for an extended period of time, often decades or more [1]. Climate change, as defined by the United Nations Framework Convention on Climate Change (UNFCC), is any change in climate that is directly or indirectly attributable to human activity and alters the composition of the global atmosphere, in addition to natural climate variability observed over comparable time periods. Numerous locations around the globe have forecast that the planet would continue to warm, with a rise in global temperature of 1.8-4.0C (average 3.0C) anticipated during the next century.

Climate change and global warming have a significant influence on Malaysia, and they should not be treated lightly. Malaysia is ASEAN's fourth largest greenhouse gas emitter, after Indonesia, Vietnam, and Thailand, accounting for 0.52 percent of world carbon emissions [2]. Malaysia's climate is tropical and humid. It is significantly influenced by the rocky terrain and intricate land-sea interactions. Malaysia may be described as a disaster-free zone as a result of climate change. However, mild climate-related disasters have increased in frequency in recent years. These floods and droughts have had a significant socioeconomic impact on the nation, but modest damage has been caused by landslides triggered by heavy rainfall and strong winds in mountainous and coastal locations. Malaysia may see temperature variations ranging from 0.7 to 2.6 degrees Celsius and precipitation changes ranging from -30 to 30%, according to forecasts based on climate modelling using 14 GCMs (Global Climate Model).

This study aims to see if there is any connection between pests damaging zoological specimen collections at natural history museums in Malaysia with climate change. This study aims to determine the causes of damaged zoological specimens and the effectiveness of the treatment used. It focused on collection management, a term applied to various methods in which museum specimens are assemble, organized, researched, interpreted, preserved, and narrowed down to identifying and treating pests, the primary agents of natural history collection loss in Malaysia. Proper collection management is essential to guarantee that the collections complement the museum's goal. Understanding the relationship between pests and climate change may help museums avoid harm to their collections.

2. METHODOLOGY

Numerous collection centres and natural history museums were chosen for their geographic and academic breadth. The selection includes collection centres in Malaysia that were identified in a paper by [3] titled 'Natural History Museum Malaysia: Planning and Development.' Eleven centres were chosen and visited in all. Prior to the visits, a call was sent to notify the curators or collection managers of the visit. Additionally, they were instructed about the objective of the trips. Three natural history museums were visited outside Malaysia for comparison reasons. Twenty-five curators and collection managers from eleven Malaysian institutions were interviewed to gain a better understanding of (i) their practises in managing zoological specimens in natural history collections, (ii) the issues and challenges they face in their institutions, and (iii) threats that have harmed their zoological specimens.

In this research, an overview of the characteristics of fungal subphylum found on the zoological specimens are provided. Fungi sample from six dried bat taxidermy skin and pinned entomological specimens were collected and transferred to petri dishes containing Sabouraud Dextrose Agar (Merck). This agar is frequently used as a nutrient medium for growing mould cultures. SDA were prepared by dissolving 65 g of the media in one litre of distilled water. The media then were heated with frequent agitation and boiled for one minute to completely dissolve the medium and autoclaved at 121^{o}C for 15 minutes. The agar was then cooled off to 40 - 50^{o}C, and poured into sterile petri dishes. When the agar plates were incubated at 25 - 30^{o}C in an inverted position for two to five days, the isolated fungal colonies were transferred to a new plate and incubated for 3-7 days at 30^{o}C for pure culture. Identification were done following Kilch (2002) by observing morphology of single colony of the fungi.

3. RESULTS AND DISCUSSION

Most of the collection dated at least ten years back. As for collection centres in Malaysia, more than 60 years old collections are already considered 'old.' However, in the Institute for Medical Research (IMR), there are some bird collections from the 1800s.. Their collection was also sorted by invertebrates, vertebrates, skin, bones, alcohol, and insects.

In Malaysia, collections older than 60 years are already considered 'old.' However, the Institute for Medical Research (IMR) has some bird collections dating all the way back to the 1800s. Additionally, their collection was divided into invertebrates and vertebrates, skin and bones, alcohol, and insects.

In the majority of the collection, insects and fungus are the predominant pests, with little harm caused by vertebrates observed. Almost all collection centres and museums surveyed were contaminated with fungi. This is corroborated by an interview with the curators and collection officers of these sites, who claimed that 62% of them had fungal infection issues and another 38% have insect infestation issues (Figure 1). The majority of fungal infections occurred inside the collecting room. However, it has been known to contaminate specimen collecting in rare instances. Additionally, insects may wreak havoc on specimens by boring them, particularly bones and insects collections. The insects drilled several holes in the specimens, causing them to become brittle. Insects do considerable harm in areas with high humidity and temperatures, in compared to the damage they produce in temperate climates [4].

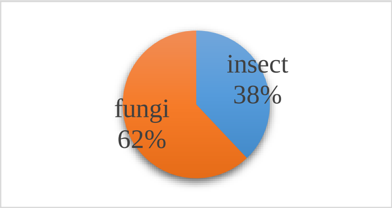

Figure 1. Type of pests damaging zoological specimens in natural history collections in Malaysia

Table 1 shows three families of insects identified by curators and collection managers in this study that caused damage to zoological specimens in their natural history collections. Ants (Order: Formicidae), silverfish bug (Order: Lepismatidae), and dermestid beetle (Order: Dermestidae) were insects commonly known as pests in natural history collections [5]. Eight out of 11institutions in this study had insects infestation. Dermestid beetles found in seven institutions.

Figure 2. Frass found in the infested pinned entomological collections

After swabbing the boxes and examining the specimens under the microscope, two species of insect pests were discovered: common house ants (Vollenhovia sp.) and dust mites (Dermatophagoides sp.). Vollenhovia sp. were visible with the naked eye and were often seen in groups of less than five individuals in a single bug box. Dermatophagoides sp. is discovered under the frass (fine powdery waste produced by insects that is largely faeces rather than pieces of the substance it is digging through or devouring) of afflicted specimens, as seen in Figure 2. Dermatophagoides is thought to be the primary allergenic component of home dust. These mites are parasitic on mammals and birds. It is often found in residences, thus the term "house-dust mite" [6]. Natural history collections are vulnerable to pest bug infestation. Natural history museums' preserved flora and animals provide natural food for pest species such as dermestid beetles. A pest infestation may have a terrible impact on a collection of little things, such as pinned insects, in a relatively short period of time. As a result, strict pest managementFungi have a number of unique traits that should be addressed when implementing integrated pest control strategies and treating them. To begin, they may disperse spores into the sky through the wind [7]. If the spores infect rooms, objects, or air conditioning systems, they may be very harmful. Second, they develop three-dimensional mycelia, a tangle of branching, tubular filaments (hyphae) capable of penetrating deep into materials. Mechanical cleaning is incapable of removing these mycelia. Even chemical washing may be insufficient to eradicate deeply established mycelia [8].

Macroscopic examination of fungal development in a bat skin sample is shown in Figure 3. Mold develops on

Table 1. Type of insects that caused damage in zoological specimens in natural history collections

Museum/Collection Centre	Formicidae	Lepismatidae	Dermestidae
Institute of Oceanography and Environment, Universiti Malaysia Terengganu	/	/	/
Forest Research Institute, Malaysia	-	-	/
Lee Kong Chian Natural History Museum	-	/	/
Museum of Zoology, Universiti Malaya	-	-	-
Zoological Museum, Universiti Kebangsaan Malaysia	-	/	/
Prince of Songkhla University	/	-	/
Natural History Museum, Putrajaya	-	-	-
Biomedical Museum, Institute for Medical Research	-	/	/
Sabah Museum	-	-	-
BORNEENSIS, Universiti Malaysia Sabah	/	-	-
Institute for Biodiversity, Department of Wildlife and Parks	-	-	-
Sarawak Natural History Museum	-	-	-
Universiti Malaysia Sarawak	-	-	-

/ : Presence -: Absence

the forearm, thumb, foot, and wing membranes. On the skin of bats, two forms of mould may be found. It appears as a fluffy white mass (Figure 3a) or as a dark, dusty greenish-grey mass (Figure 3b) (Figure 3 b).

Fungus infection on entomological specimens was more uniform, since all affected specimens had white filamentous fungi growing on them throughout their bodies (Figure 4). [9] Several Native American long weapons in locked storage cabinets at the Alaska State Museum (ASM) contain an odd fluffy white material on their surfaces. This material resembled our mould in looks and characteristics, and it was discovered on wood, bone, ivory, leather, and feathers.

Figure 3 shows a macroscopic observation of fungal growth in a bat skin sample. The forearm, thumb, foot, and wing membranes are the spots where mold grows. Two types of mold can be seen on the skin of bats. It is either a fluffy white mass (Figure 3a) or a dark, dusty greenish-grey (Figure 3b).

Figure 3. Macroscopic observation of fungi growth on bat taxidermy skin specimens (a) Fluffy white mass; (b) Dark dusty greenish grey

Fungi infestation on entomological specimens was more homogenous as all infected specimens were found with white filamentous fungi all over their body (Figure 4)[9]. Some Native American long weapons in the Alaska State Museum (ASM) closed storage cabinets have an unusual fluffy white substance on their surfaces. This substance had a similar appearance and characteristic of our mold, and they were found on the objects such as wood, bone, ivory, leather, and feathers.

Three different species of fungus were discovered to be present in the zoological collections. There are three species involved: *Aspergillus* sp., *Mucor* sp., and *Chaetomium* sp. *Aspergillus* sp. is a common airborne mould that is regularly found on items of cultural heritage. Indeed, *Aspergillus* sp. was discovered in Ichthyology and Herpetology skeletal collections [10] as well as in exterior (ear) and internal (saliva and anal swab) bat body parts [11], indicating that Aspergillus sp. has a broad range of moisture content. The literature demonstrates that common surface fungi such as *Aspergillus* sp. have a broad range of moisture content. Dormant conidia, on the other hand, are classified into two types depending on their moisture content: low and high. Conidia with a moisture level of 6 to 25% have a low moisture content, while conidia with a moisture content of 50 to 80% have a high moisture content. On the other hand, xerophytic (dry-loving) fungi may germinate even when the relative humidity is less than 60% [12]. *Chaetomium* is a genus of dematiaceous (dark-walled) fungus belonging to the Chaetomiaceae family. This genus is often seen on historic items. They cause damage to fabrics, paper fibres, and other materials composed of cellulosic cellulose [13]. These saprobic ascomycetes are often found in dung, straw, paper, feathers of birds, seeds, plant detritus, soil, and air [14].

Chaetomium sp. was discovered in taxidermic skin samples of bats in this study. *Mucor* species (Mucorales, Mucoraceae) are found globally and may be isolated from practically any organic substance that comes into contact with air. *Mucor* spp. has been isolated from a variety of substrates, including soil, decaying plant waste, and dung from air samples, as well as as a parasite on other fungus in one example [15]. *Mucor* spp. is most often associated with rotting microbes.

In natural history collections, managing the collection environment is critical for long-term preventative conservation [16]. A well-managed environment safeguarded collections and enhanced the working and living conditions of staff and visitors. Consider the numerous factors that affect environmental management for natural history collections [17]. Southeast Asia lies wholly inside the warm, humid tropics, with a monsoonal climate marked by wet and dry seasons. Rainfall is more closely associated with seasonal changes than temperature variations. However, the area has a high degree of climatic complexity. These components contribute to pests that devastate specimen collections. Dry materials such as bone, shell, and coral are more resistant to degradation, however they may still be harmed for a variety of causes. When exposed to ultraviolet (UV) rays in natural and artificial light, the pigment of specimens (even taxidermy) fades [18]. Warm surroundings may cause leftover fats in the skin to be released, resulting in hair or feather loss. Dry surroundings may result in the breakage or delamination of specimens such as turtle shells, horn, and bone. Relative humidity variations may cause bone to inflate and collapse [19]. If the oscillations are excessively rapid or violent, the bone might shatter and disintegrate. This form of oscillation is often caused by excessive illumination in displays that is switched on and off on a regular basis. Teeth are especially susceptible to low relative humidity, which results in fractures and peeling.

According to the food sources they seek, common insect pests in natural history collections may be classified as follows: textile or fabric pests, wood pests, stored goods pests, paper pests, and general pests [20]. Additionally, they may be classified according to their behaviour and mode of control [21]. Additionally, neither

Vollenhovia sp. nor *Dermatophagoides* sp. are well-known as pests. The presence of *Vollenhovia* sp. may be a result of the building environment. All insects enter the structure in unique ways and make their way to the collections. Boring woods insects may cause significant harm to museum items. However, since their growth is sluggish (several years, with the exception of Lyctus species), the invasion must be disregarded for years. Typically, wood-boring beetle larvae are brought into collections together with afflicted artefacts. Controlling the humidity is already an efficient strategy to halt or limit the growth of many species. Additionally, it defines five primary access points for insects: they might crawl or fly in from the outside, hitchhike with things, enter as a result of associated activity, enter with food, or already reside inside the structure or fabric of the building. Numerous insect pests are able to survive and thrive in buildings due to their capacity to feed on organic soil and trash [22]. This may be why *Dermatophagoides* sp. was found in the entomological samples used in this investigation. A building's excessive level of filth and trash obviously increases the danger of insect infestation.

Proper building construction and subsequent care are critical for keeping pests out of a structure [20]. Numerous insects discovered in collections are not active pests but have made their way inside the structure. While none of these invertebrates poses a direct threat to the collection, they may offer a significant food supply for pests such as carpet beetles [23]. Excellent circumstances prohibit insects from reproducing, whereas locations with temperatures of 20°C or above promote bug reproduction. While it may not be practicable to decrease temperatures in public places, object storage should be kept at the lowest possible temperature. However, take care not to allow relative humidity levels to climb to unacceptably high levels. Bear in mind that even in cool places, direct sunshine may generate localised hot patches, and preventative measures such as providing shade should be implemented. Additionally, inconsistencies in temperature might result in localised condensation.

While climate change is a divisive issue, there is little doubt that numerous environmental conditions will continue to impact insect dispersion in the future. The most obvious effect is a rise in average temperature, which has a variety of ramifications for insect populations. Climate change will have an indirect effect on pest species that inhabit buildings such as museums and historic homes, as well as on outside conditions and pest species. [24] Even though temperature increases are just a few degrees on average over the next century, they may have substantial repercussions, such as increased melting in Greenland. Insects' ranges may expand northward in the future century, and existing insects may spend more time inside in warmer climates [25]. Even if insects are protected from the elements outside, temperature rises outside are likely to have an effect on inside temperatures.

Malaysia's climate is tropical and humid. It is significantly influenced by the rocky terrain and intricate land-sea interactions. Malaysia might be described as a disaster-free zone as a result of. Managing the collection environment is essential for long-term preventive conservation in natural history collections [16]. A well-managed environment protected collections and improved working and living circumstances for personnel and visitors. Consider the various elements that influence environmental management for natural history collections as a simple approach [17].

Southeast Asia is located entirely inside the warm, humid tropics, and its climate is monsoonal, with rainy and dry seasons. Rainfall is more closely related to changing seasons than temperature differences. The region does, however, have a significant degree of climate complexity. These elements play a role in pests that wreak havoc on specimen collections. Dry materials like bone, shell, and coral are more resistant to deterioration, although various reasons can still harm them. Pigment in specimens (including taxidermy) fades when exposed to ultraviolet (UV) rays in daylight and artificial light [18]. Warm environments can cause the release of residual fats in skins resulting in hair or feather loss. Dry environments can cause specimens like turtle shells, horn, and the bone to break or delaminate. Variations in relative humidity can cause bone to swell and compress [19]. The bone can crack and break apart if the oscillations are too quick or severe. Excessive lighting in showcases that is turned on and off daily basis is a common cause of this type of oscillation. Teeth are particularly vulnerable to low RH, which causes them to fracture and peel.

Figure 4. (a-c) Fungi infection on pinned entomological collections

Common insect pests in natural history collections can be categorized into the following groups based on the types of food sources they seek: textile or fabric pests, wood pests, stored product pests, paper pests, general pests [20]. They can also be categorized according to their behavior and means of control [21] All insects have various ways of entering the building and reaching the collections. The species of boring woods beetles can result in large damages to museum objects. However, due to their slow development, the invasion must be overlooked for years. Most of the time, the larvae of the wood-boring beetles are transported with infested objects into the collection. Both *Vollenhovia* sp. Moreover *Dermatophagoides* sp. are not commonly known as pests. The building environment may cause the presence of *Vollenhovia* sp. in the insect boxes.

For many species, regulating the humidity is already an effective way to stop or slow down the development. It also distinguishes five main routes of entry for insects: they can creep or fly in from the outside, hitchhike along with objects, enter with related activities, come along with food, or already live in the structure or fabric of the building. Many insect pests survive and succeed in buildings because of their ability to live organic dirt and debris [22]. This may be the reason for the occurrence of *Dermatophagoides* sp. in the entomological collections for this study. The high amount of dirt and debris in a building will inevitably increase the risk of pest infestation.

Good building construction practice and subsequent maintenance are essential if pests are kept out of a building [20]. Many insects found in collections are not active pests but have strayed into the building. Though both invertebrates may not present an immediate risk to the collection, they can provide a substantial food source for pests such as carpet beetles [23]. Excellent conditions will discourage insects from breeding, and any areas with temperatures of 20°C and above will encourage insect breeding. Although it may not be possible to lower temperatures in public areas, object stores should be at as low a temperature as is practical. However, ensure that the relative humidity levels are not permitted to rise to unacceptable levels. Remember that direct sunlight can cause local hot spots even in cool areas, and preventive measures such as providing shading should be taken. Also, uneven temperatures can result in localized condensation.

Climate change is a contentious topic, but there is no question that various environmental factors will influence insect dispersal in the future. The most visible of these is an increase in average temperature, which can have various consequences for insect populations. Climate change will have an indirect impact on pest species that dwell in structures, such as museums and historic residences, and outdoor circumstances and pest species. [24] Temperature changes during the next century, even if they are only a few degrees on average, can have significant consequences, such as greater thawing in Greenland Insects may increase their range northward in the coming century, and current insects may have extended periods of activity indoors in warmer climates [25]. Even though insects are sheltered from the elements outside, increases in outside temperatures are likely to impact indoor temperatures.

Malaysia's climate is tropical and humid. It is significantly influenced by the rocky terrain and intricate land-sea interactions. Malaysia may be described as a disaster-free zone as a result of climate change. However, mild climate-related disasters have increased in frequency in recent years. These refer to floods and droughts that wreaked havoc on the country's socioeconomic fabric, whereas landslides induced by extreme rainfall and strong winds in mountainous and coastal regions did minor damage. Forecasts based on climate modelling using 14 GCMs (Global Climate Models) indicate that Malaysia may see temperature fluctuations of between 0.7 and 2.6 degrees Celsius, as well as precipitation variations of between -30 and 30%. [26] Sea level rise, decreased crop yields, increased disease incidences among forest species, biodiversity loss, shoreline erosion, increased flood intensity, coral reef bleaching, increased disease incidences, tidal inundation of coastal areas, decreased water availability, loss of biodiversity, and increased droughts are just some of the potential impacts of climate change in Malaysia.

Aspergillus sp., *Chaetomium* sp., and *Mucor* sp. are often encountered fungus in natural history collections, and their presence in our research is unsurprising. While the insects discovered in this study are typically referred to be home pests, they may become a nuisance at museums. Low temperature and alcohol treatment demonstrated to be the most effective non-pesticidal strategy for zoological collection rehabilitation. To maintain the value of a natural history collection, it must be cared for, conserved, and subjected to ongoing scientific input. Establishing a pest-free environment is difficult, but it should be done for the sake of natural history collections; the highest standards of care and construction practises are required to exclude insects.

AUTHORS' CONTRIBUTIONS

Arney Sapaat. and Siti Fatimah Sabran conceived of the presented idea. Prof. Emeritus Datin Dr. Maryati Mohamed encouraged to investigate on the connection between museum pest and climate change and supervised the findings of this work. All authors contributed to the final text by discussing the findings and revising it.

ACKNOWLEDGMENTS

Thank you UTHM for providing platform that made this research possible and to Grant Tier 1 Vot No Q010 for their partial assistance We thank all curators and collection managers who provided insight and expertise that greatly assisted the research.

REFERENCES

[1] IPCC, Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. & Hanson, C.E. (eds.). Cambridge, Cambridge University Press, 2007.

[2] H.A. Rahman,Climate Change Scenarios in Malaysia: Engaging The Public, International Journal of Malay-Nusantara Studies, vol. 1(2), 2018, pp. 55-77.

[3] F.S.P. Ng, (ed), Natural History Museum Malaysia: Planning and Development, UNDP & FRIM, Kuala Lumpur, 2008.

[4] O.P. Agrawal, Conservation in South and Southeast Asia, In Wise, C. and Erdos, A. (eds.), Museum, vol. 27 (4), 1975, pp.161-165

[5] D.B. Pinniger, & J.D. Harmon, Pest management, prevention and control. In: Carter, D. & Walker, A. (eds), Chapter 8: Care and Conservation of Natural History Collections, Oxford, Butterwoth Heinemann, 1999, pp. 152 - 176.

[6] H.A. Denmark, & H.L. Cromroy, House dust mite, Dermatophagoides spp. (Arachnida: Acari: Pyrogliphididae), *UF/IFAS Extension*, EENY-059, 2017.

[7] D. Pinniger, New developments in pest management for collections in museums and historic houses, In. Robinson, H. & de Carvalho Campos, A.E. (eds), Proceedings of the Seventh International Conference on Urban Pests, Biological Institute, Sao Paulo, Brazil. 2011, pp. 17-21

[8] P. Querner, D. Pinniger, H. Astrid, Integrated Pest Management (IPM) in Museums , Archives and Historic Houses - Proceedings of the International Conference in Vienna , Austria 2013 Section I : IPM in Museums. 9-68, 2013.

[9] C.A. Pack, A Fungus among Us: Mold Growth in Museum Environments, University of Delaware, US, 2011.

[10] C.E. Thacker, R.F. Feeney, N.A. Camacho, & J.A. Seigel, Mold Removal and Rehousing of the Ichthyology and Herpetology Skeletal Collections at the Natural History MuseuOccum of Los Angeles County. Copeia, vol. 4, 2008, pp. 737–741.

[11] S.S. Jaya Seelan, F.A. Anwarali Khan, M. Sepiah, & M.T. Abdullah, Bats (chiropteran) reported with *Aspergillus* species from Kubah National Park, Sarawak, Malaysia, Journal of Tropical Biology and Conservation, vol. 4(1), 2008, pp. 81-97.

[12] Florian, Mary-Lou, Heritage Eaters: Insects and fungi inheritance collections, London, James and James, 1997.

[13] O. Abdel-Kareem, Monitoring, controlling and prevention of the fungal deterioration of textile artifacts in the museum of Jordanian heritage, Mediterannean Archeology and Archeometry, vol. 10(20), 2010, pp. 85-96

[14] D. Liu, & R.R.M. Paterson, Chaetomium. In. Liu, D. (ed), Molecular Detection of Human Fungal Pathogens, CRC Press, Florida, US, 2011, pp. 389-391.

[15] C.W. Hesseltine, Genera of Mucorales with notes on their synonomy. Mycologia, vol. 47, 1955, 344-363.

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

[17] S. Michalski, Care and Preservation of collections. In. Boylan, P.J. (ed), Running a Museum: A practical Handbook, ICOM, France, 2004, pp. 51-91.

[18] C. Antomarchi, S. Michalski, Z. Aslan, A. Sabik, C. Malapitan, M. Foulquié, & J.L. Pedersoli Jr., A guide to risk management of cultural heritage, ICCROM-ATHAR, Sharjah, UAE, 2016, pp. 117.

[19] J. Bacharach, Chapter 4. Museum collections environment. In. National Park Service (NPS), Museum Handbook: Part 1, NPS Museum Management Program, Washington DC, 2016. pp. 3-26.

[20] (NPS). National Park Service, Museum Handbook: Part 1, NPS Museum Management Program, Washington DC, 2018, pp. 16-24.

[21] A.W. Brokerhof, Assessing and managing pests risk in collections. In. Querner, P., Pinniger, D & Hammer, A. (eds), Proceedings of the International Conference entitle Integrated Pest Management (IPM) in museums, archives and historic houses, Section 1: IPM in museums, Vienna, Austria, 2013, pp. 31-43.

[22] D. Pinniger, New developments in pest management for collections in museums and historic houses, In. Robinson, H. & de Carvalho Campos, A.E. (eds),

Proceedings of the Seventh International Conference on Urban Pests, Biological Institute, Sao Paulo, Brazil, 2011, pp. 17-21.

[23] D. Pinniger, & P. Winsor, Integrated pest management A guide for museums, libraries and archives, Museums, Libraries and Archive Council, London, 2004.

[24] P. Brimblecombe, P. Lankester, Long term changes in climate and insect damage in historic houses, Studies in Conservation, vol. 58(1), 2013, pp. 13-22.

[25] R.E. Child, Insect Damage as a Function of Climate, In: T. Padfield & K. Borchersen, eds. Museum Microclimates, Copenhagen: National Museum of Denmark, 2007.

[26]www.met.gov.my/.../metmalaysia/.../socioeconomic impactsofextremeweatherandclimate