INTEGRATED PEST MANAGEMENT IN HISTORICAL COLLECTIONS OF THE 21st CENTURY

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by

Joshua Tyler Freimark

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CERTIFICATION OF APPROVAL

I certify that I have read *Integrated Pest Management in Historical Collections of the 21st Century* by Joshua Tyler Freimark and that in my opinion this work meets the criteria for approving a thesis submitted in partial fulfillment of the requirements for the degree: Master of Arts in Museum Studies San Francisco State University.

Edward Luby
Professor of Museum Studies

Jean Demouthe
Lecturer of Museum Studies

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Joshua Tyler Freimark
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Many museum collections are at risk for pest infestation, but historical collections in particular are susceptible to these degradations due to the prevalence of materials that attract pests. In the past, collections have been treated with chemical methods, but more recently, a new methodological approach, called Integrated Pest Management, or IPM, has emerged in caring for collections. In this thesis, Integrated Pest Management, defined as an integrative method of pest control, is examined in museums caring for historical collections. A survey of museums in North America that care for historical collections was conducted, resulting in a response rate of roughly 20%. After a discussion, a set of conclusions and recommendations is offered. It is concluded that museums with historical collections have largely integrated IPM into their efforts and that IPM is a significant advance in collections stewardship over traditional methods.

I certify that the text of this abstract is an accurate representation of the content of this thesis

Edward Luby, Professor of Museum Studies	5-20-15 Date

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Chapter 1: Introduction

Pests can be a major source of damage to historical collections in museums, as the Detroit Museum of Art learned in 1995 from its infestation of mold that caused thousands of exhibits to be infested. While collections have been treated with chemical methods for some time, more recently, a new methodological approach, called Integrated Pest Management, or IPM, emerged in caring for collections. IPM is defined as an integrative method of pest control, seeking to be proactive rather than reactive, and preventing infestations rather than exterminating them as they are found, using any method that would solve the problem without the use of fumigants and other toxins.

In this thesis, Integrated Pest Management in museums caring for historical collections will be examined. Many museum collections are at risk for pest infestation, but historical collections in particular are susceptible to these degradations due to the prevalence of textiles, furs, wood, bone, and other materials that attract pests. Many pests infest museums, but the four most prevalent are cockroaches, termites, silverfish, and webbing clothes moths (to be detailed later in the body of this thesis). IPM is a relatively new field, and it is not ubiquitous in the museum field, but it has become increasingly prevalent in the last 20 years, starting with federally funded museums such as the Smithsonian. IPM involves mechanical techniques (blocking pest access), cultural techniques (rules forbidding behaviors that attract pests, such as food and drink), biological techniques (studying pests, discovering their weaknesses, and attacking them), observatory techniques (keeping watch of pest infestations), and chemical techniques (green pesticides, pheromones, or other non-toxic chemicals that thwart pests). Being proactive, many museums cite housekeeping and vigilance as a major part of their pest control policies.

To address these important questions, this thesis will detail the history of pest control (both IPM and traditional pest control methods) and will outline actual processes of IPM as practiced in broader museum community, incorporating biological studies of the insects and pests in question, behavioral studies, and chemical and mechanical processes of pest control. By conducting a literature review of the topics outlined above, as well as a survey of museums in North American that care for historical collections, a snapshot of IPM practice in the history museum sector will be offered.

While Integrated Pest Management techniques have already been adapted by many larger museums, such as the Smithsonian Institution and the American Museum of Natural History, some smaller museums, which often include historical collections, may still utilize traditional pest treatment methods. At the same time, little is known about IPM in museums that care for historical collections. Significantly, the Heritage Health Index (HHI), one of the few analyses of collection health, has also pointed out that "2% of American museums have had significant damage caused by pests, illustrating the risk of pest infestation, and the need for analysis" (HHI, 2004) (Appendix 1).

While IPM is useful to all types of museums, these methods (particularly basic housekeeping and vigilance, as will be discussed throughout the body of the thesis) are of the utmost importance to museums with historical collections and archives, due to the prevalence of textiles, leathers, paper and other materials that are held within them, all of which are preyed upon by pest infestation. Indeed, the HHI notes that 14% of those collections in "urgent need of care" are either textiles or unspecified ethnographic collections, items which can be found in historical collections (HHI, 2004) (Appendix 1).

In this thesis, a literature review will be presented in Chapter 3. In the first part of the literature review, the history of pest management will be covered. The second part will cover basics of collections management. The third section will give an overview of common pests in museums.

While there has been a fair amount of literature published on IPM since the early 1990s, ranging from pest control plans written by accredited museums, textbooks on IPM and entomology, conference presentations, to name just a few, some of the literature, while thorough in the information and techniques conveyed, was written by IPM consulting firms, and thus, it seeks to proselytize IPM to potential customers. As a result, in the literature review, sources published by companies are always identified as such, and were used judiciously, since they may not have been subjected to the same kind or peer review as academic textbooks and articles.

In Chapter 2, the Methods used in the thesis, which consist of a literature review and a survey, are outlined. The survey of North American museums that care for historical collections was distributed to 95 museums. The process for developing and distributing the survey, as well as each question asked, is also outlined in this chapter.

In Chapter 4, the Results of the survey are presented, followed by a Discussion of the survey in light of the literature review, in Chapter 5. Finally, in the Conclusions and Recommendations, four Conclusions concerning IPM in museums that house historical collections are presented, followed by three recommendations.

IPM is ultimately important because museum collections, particularly historical collections, are susceptible to pest infestation. If utilized properly, IPM is an effective pest deterrent that is both cheaper and more environmentally friendly than traditional approaches, and while improper usage cannot harm humans the way pesticides can, the use of IPM properly as a an approach to preventative care can help support the care of North America's irreplaceable historical collections.

Chapter 2: Methods

The methods in this thesis consisted of a literature review and a survey, as outlined below. The literature review was conducted in order to supply context to the national survey, which was sent to 95 museums in North America that possessed historical collections. Museums with historical collections were selected as an emphasis of study because historical collections are usually associated with a wide range of organic materials, including wood and textiles, which are attractive to pests, and in order to supply an important snapshot of practices in a part of the museum world which faces major challenges in caring for its extensive collections.

Literature Review

The literature review first examined the history of pest management, beginning with traditional methods and culminating in a discussion of how integrated pest management developed as a system for the modern day museum. Sources include several IPM textbooks, information gathered from attending the 2014 National IPM Conference in Williamsburg, Virginia, several IPM textbooks, and information gathered from the web sites of individual museums.

Next, the literature review examined collections management basics, with an emphasis on collections management issues involving historical collections. Sources included key textbooks and websites on collections care and maintenance. This section emphasized both the basics of collections management and how it relates to historical collections in particular.

The collections management chapter was followed by a review of pests common to the museum environment. As outlined in this chapter, the most common museum related pests are attracted to the content of museums, particularly history museums, due to the high amount of organic materials housed within these institutions. The chapter also discussed which types of collections are preyed upon by which types of pests.

The final section of the literature review discussed IPM and particular pest management techniques, including outlining the background and range of approaches, the costs of techniques, and important considerations and key factors associated with each technique.

Overall, information from the literature review was derived from recognized publications in collections management and scientific journals concerned with IPM. Publications from the University of Toronto, the University of California, the University of Nebraska, Colorado University, and Oxford University were consulted, as well as specific IPM publications such as *The IPM Practitioner*, *Studies in Pest Control*, and articles from the Federal Department of Agriculture, and entomology textbooks including *A Field Guide to Common Texas Insects*. In addition, the IPM policies of museums posted on their museum web pages were consulted, such as those from the Smithsonian Institution, the American Museum of Natural History, and the Getty Museum; however, these museums were not part of the survey outlined below.

The Survey

A survey of museums associated with historical collections was developed after a review of the relevant literature was completed. The full survey, which consisted of 15 check-box or open-ended questions, with some questions posing subsets of questions, is presented after the Appendices.

In general, the survey asked museums about their practices in managing pests, specifically asking questions about the climate in that region, methods of pest control utilized, and common recurring pest infestations, as well as a series of demographic questions, such as the region the museum was located in, the size of the institution, and estimated annual visitors, so that comparisons between museums might be analyzed. Questions also asked about housekeeping plans, infestation, treatment, square footage, and security.

Museums with historical collections were selected because, as mentioned above, museums with historical collections usually house a wide range of organic materials which are attractive to pests, and because this sector of the museum world faces major challenges in caring for its collections. Museums to be surveyed were selected by reviewing the list of museums either accredited or on the path to accreditation by the American Alliance of Museums (AAM), as outlined on the AAM web page (AAM, 2015) (Appendix 2). Accredited museums (or those on the path to accreditation) were selected because they adhere to best practices in collections stewardship. Museums that appeared to have historical collections based upon their website were then randomly selected, for a total of 94 museums, so that a snapshot of practice across the field could be obtained.

A sample of museums surveyed are listed in Table 1. The survey was sent to a total of 95 museums, all of which house historical collections, with a personalized cover letter for each institution. The surveys were mailed out in spring, 2015, in self-addressed stamped envelopes using a personal return mail address.

Table 1. Museums Surveyed

NAME OF MUSEUM	**LOCATION**
1. Jack Hadley Black History Museum	Alabama
2. Old Governor's Mansion	Alabama
3. Watson Brown Foundation	Alaska
4. State House Museum	Arkansas
7. Railway Museum	California
8. East Terrace House	California
9. Haggin Museum	California
10. Cordova Historical Museum	California
11. Northern California Historical Society	California
12. Museum of the African Diaspora	California
13. Gilb Museum	California
14. Margaret Herrick Library	California

15. Dunsmuir House	California
16. History Colorado	Colorado
17. Hartford Museum	Connecticut
18. Harriet Beecher Stowe Center	Connecticut
19. National Archives	DC
20. Museum of Afro-American History	DC
21. Morrison Flagler Museum	Florida
22. Vizcaya Museum	Florida
23.Margaret Mitchell House	Georgia
24. East Side Heritage Center	Georgia
25. Marrieta Museum of History	Georgia
27. Explorations in Antiquities Center	Georgia
28. Museum of History	Georgia
29. Telfair Museum	Georgia
30. War in the Pacific National Park	Guam
31. Iolani Palace	Hawaii
32. Grout Museum	Idaho
33. Snowden House	Idaho
34. Rennsaeler House Museum	Idaho
35. Chicago History Museum	Illinois

36. Ulrich Museum	Kansas
37. Frankfurt Historical Society	Kentucky
38. Brick Store Museum	Maine
40. Concord Museum	Massachusetts
41. Connecticut Valley History Museum	Massachusetts
42. Old State House Museum	Massachusetts
43. Kalamazoo Valley Museum	Michigan
44. Arab American National Museum	Michigan
45. Holland Historical Trust	Michigan
46. CR Smith Museum	Michigan
47. Bell Museum	Minnesota
48. Stuhr Museum	Nebraska
49. Currier Museum	New Hampshire
50. Morris Museum	New Jersey
51. Albany Institute of History	New York
52. George Eastman House	New York
53. Chi Phi Fraternity Museum	New York
54. National Archives	New York
55. Pocantico Center	New York
56. Northeast Historical Society	New York

57. Greenville Museum	North Carolina
58. Hickory Museum	North Carolina
59. National Underground Railroad Center	Ohio
60. Allen County Museum	Ohio
61. Oklahoma City Historical Center	Oklahoma
62. Center for Wooden Boats	Oregon
63. Independence Seaport Museum	Pennsylvania
64. National Canal Museum	Pennsylvania
65. Lehigh County Historical Society	Pennsylvania
66. National Museum of the 8th Air Force	South Carolina
67. Rocky Mount Museum	Tennessee
68. Sixth Floor Museum	Texas
69. Museum of South Texas History	Texas
70. Earle-Napier Kinnard House	Texas
71. De Walt Heritage Center	Texas
72. HMNS Sugarland	Texas
73. Harry Ransom Center	Texas
74. Fort Vancouver Historical Trust	Texas
75. Moore Ace of Clubs House	Texas
76. Sam Houston Memorial	Texas

77. North Houston History	Texas
78. Moore Ace of Clubs House	Texas
79. National Museum of the Marine Corps	Virginia
80. Woodrow Wilson Library Foundation	Virginia
81. Alexandria Black History Museum	Virginia
82. Fort Ward Museum	Virginia
83. Firehouse Museum	Virginia
84. Stabler Apothecary Museum	Virginia
85. Washington History Research Center	Washington
86.Washington State University Art	Washington
87. Kittitas County Historical Museum	Washington
88. Yakima Valley Museum	Washington
89. Puget Sound Museum	Washington
90. Washington State History Museum	Washington
91. East Washington State History Museum	Washington
92. Harper's Ferry Museum	West Virginia
93. Wisconsin Maritime Museum	Wisconsin
94. Wyoming State Museum	Wyoming
95. Montreal Holocaust Memorial	Canada

The survey consisted of 15 questions, as outlined below. Question 1 asked several questions. Question 1a asked for the geographic region of the museum within North America, with responses consisting of Northwest, Southeast, Midwest, Southwest, and North. Question 1b asked about the size of the museum collection: small (less than 10,000 objects), medium (10-50,000 objects), and large (more than 50,000 objects). Question 1c asked about the title of the staff member who had completed the survey, and how many other staff members assisted this person in pest control. Question 1d asked how many employees (part time, full time, and volunteer) the museum has.

The second question asked about IPM issues within the organization, with instructions to check whichever are applicable: building structure maintenance, internal climate control, infestations, insufficient budget, a lack of a modern HVAC system, and other.

Question 3 asked specifically about the IPM plan, with several sub-questions: 3a asked if the museum possessed a formal plan, while 3b asked about the features of the plan (if applicable).

Question 4 pertained to prevention, asking which preventative measures the museum used for its pests (4a), and whether or not the museum had designated quarantine zones for infested objects (4b). Question 5 asked about treatments, asking if the museum utilized any of the following: pesticides, CO2, argon, microwave, heat/freezing, nitrogen, green pesticides, or other.

Question 6 asked how non-food waste was disposed of (specifying paper, plastic, and general garbage). This question was further split into two sub-questions: 6b asked if waste was removed and bagged on a daily or weekly basis; 6c asked how housekeeping tasks are assigned to the staff; and 6d asked if any other housekeeping methods were used.

Question 7 pertained to food: 7a asked if there was a cafeteria near the collections area. If "yes" was stated, 7b asked if waste was removed on a daily or weekly basis; 7c asked where the waste was stored pending removal; and 7d asked respondents to specify if any cleaning or maintenance procedures were involved in housing or removing food related waste.

Question 8a concerned museum collections, and asked whether pest infestation has caused destruction or deterioration, and was followed by 8b, which asked how recurrence has been prevented. Question 9a asked where collections are stored (basement, attic, off site, all collections on display, or other); 9b asked if each collection room is sealed; 9c asked about the types of storage furniture used (wood or metal, shelves, cabinets, and/or drawers); 9d asked if there were functioning HVAC systems leading into the storage areas; and 9e asked about windows in the storage area.

Question 10 pertained to housekeeping: 10a asked if there was a formal housekeeping plan. Question 10b stated, “if 10a was answered yes, then what procedures are used?” while 10c asked if any of the following materials are stored alongside the collections: newspaper, supplies, tools, cardboard, wood, or other packaging materials.

Question 11 asked about the schedule of building inspections: 11a asked if the exterior is inspected for pest access points; 11b asked," if so, how often?"; 11c asked if the following areas were inspected: downspouts, gutters, lights, roof, windows seals, and the foundation; and 11d asked if any other areas were inspected.

Question 12 asked about the exhibit areas: 12a asked about the square footage of exhibit space, 12b the approximate age of exhibit cases, 12c the schedule of pest inspection, 12d if the cases are sealed to the bases, 12e if ventilation leads into the exhibit areas (and how often they are inspected), and 12f how often the exhibit area is cleaned.

Finally, Question 13 asked if the museum contracts with pest control services, and for which issues, if applicable, and 13b asked which products are used by these services. Question 14 asked if the museum has an IPM plan, and which resources were used for the development of it. The 15th and final question asked about the process for development and approval of the institution's IPM plan, if Question 14 was answered "yes."

In the next chapter, the results of the survey are presented in a question-by-question manner, followed by a discussion chapter, where the results of the survey are discussed. The thesis ends with a conclusions and recommendations chapter.

Chapter 3: Integrated Pest Management Basics

History of Pest Management

Integrated Pest Management (IPM) is defined as a preventative, long term, low-toxicity method of controlling pests (Chicora, 2005). Modern IPM was, in actuality, first devised for use in organic agriculture, but many museums, libraries, and archives are finding IPM useful for their practices (Chicora, 2005).

The concept of IPM can arguably be traced back to the beginnings of the concept of pest management itself--pests have existed, and have been a problem, as long as humankind has been sedentary. Pests have existed for much longer than humanity itself, and they were more than capable of adapting to human societies to survive and thrive on our manufactured materials. Book lice, for example, in nature one of many wood-boring pests, easily consume books and other paper materials, which are by definition dead wood. Other pests prey upon the fur, feathers, and eggshells of animal carcasses, linen, wool, and other anthropogenic textiles in their diet (Jones, 2014).

Historically, there are records of pests dating back to ancient Egypt (Jones, 2014), ancient Rome, and other civilizations of antiquity--Egyptian tombs have revealed evidence of habitation and damage by several types of pests, such as *Stegobium paniceum* (the drugstore beetle); the biological genus *Lasioderma* (a genus comprising 50 individual species, several of whom are invasive pests); *Dermestes lardarius* (commonly referred to as the larder beetle); and biological genus *Gibbium* (another widespread genus of beetle comprising many species, many of whom are also pests). Similarly, there exist examples of the genus *Sitophilus* (a grain eating weevil), in ancient Roman records (Jones, 2014).

The 19th century, an age of increased trade and maritime expeditions, also saw a corresponding increase in pests (acting as invasive species to areas they had never existed in previously), including spider beetles (family Ptininae), and the webbing clothes moth (*Tineola bisselliella)* (Jackman, 1998).

The development of air travel in the 20th century, leading up to today's age of globalization, has naturally seen a corresponding increase and spread of pests as well. Some examples of the current spread of invasive pest species are: *Anthrenes verbasci*, the varied carpet beetle that is native to Europe but has spread to the Americas in recent years. This process has also gone in reverse: the Brown Carpet Beetle (*Attagenus smirnovi*) was found in Western Europe starting in 1979, presumably having spread from the Americas and gone eastward. The exchange of pests among nations, unwittingly and alongside artifacts that are intentionally transferred between nations, has continued until the present day (Jones, 2014).

As with records that disclose pests being found throughout history, records of attempts at pest control are also documented. Indeed, it has been hypothesized that the common house cat (*Felis domesticus*) was domesticated purely to be a predator of rats, mice, and other vertebrate pests. As this would undoubtedly lead to its own associated problems in a museum setting, this is not a practical solution for rodents, and would not help at all for the numerous insect pests that are found in museums. This is what led to the development of what are known as traditional methods of pest control--largely the use of noxious chemicals that are designed to kill the pests, such as arsenic, mercury, DDT, and other noxious chemicals. As the American Museum of Natural History (hereinafter referred to as AMNH) Paleontology Division Management Policy highlights, “Fumigants worked in preserving collections for the future in terms of controlling the infesting pest populations, but now it was becoming increasingly clear that there was a danger to humans, and in recent years this became of greater concern, and alternative means were sought" (AMNH, 2005) (Appendix 3).

While the use of toxic chemicals are certainly effective, these methods are also expensive and potentially harmful to human visitors, and thus expose museums to liability and other business risks.

The task of traditional pest control was done by collections staff known as "preparators," such as those associated with the Smithsonian Institution in the 19th and early 20th centuries. These museum personnel would utilize tobacco, camphor, arsenic, sublimate, and mercury chloride for pest preservation purposes, undoubtedly effective as insecticidal agents, but their use demonstrated a lack of knowledge about the safety of handling the objects, or the structural integrity of the objects themselves. However, it is interesting to note that there are references from the later 19th century of heat treatments being used to control pest infestation. Additionally, baths of chemical solvents, followed by impregnating the objects with wax, were used until the 1940s (Ballard, 2005) (Appendix 4). Similar techniques were used in the prior century to act as preservatives for Army uniform preparation, particularly to keep them free of clothes moths. The archives of the Smithsonian Institute have numerous recipes for arsenical baths for the purposes of pest extermination: "A quart of water...one pound of arsenic, add to 30 gallons of water. Specimens should be soaked for a period between two days and one week" (Goldberg, 1996: 60). There is also a different recipe, with a smaller ratio of arsenic, for use on taxidermied skins and feathers (Goldberg, 1996: 61).

To be more accurate, choices of pest control devices would be warranted based upon the types of collections infested, which indicates that even in this metaphorical "dark age" of pest control, a small degree of concern was shown for the relation of the pest control method to the exhibited object (i.e., botany specimens would be treated differently from mineral/geological specimens). And to be perfectly fair, some researchers have always been concerned with the adverse effects on human health that pesticide use can bring-in the 18th century; for example, the deleterious effects of mercury were already recognized: "Corrosive sublimate [mercury] is a dreadful poison...which should be entrusted only to an artist..." (Goldberg, 1996: 63).

The 1940s saw a greater use of chemical pesticides, including a 5% DDT solution recommended by the Department of Agriculture, which was utilized on all incoming collections until 1969, when the Smithsonian Institution began to employ other methods of pest control beyond fumigation. Measures such as object monitoring, isolation, and vacuuming became common and recommended procedures in the 1970s. In the 1990s, freezing units were purchased, storage drawers were fitted with traps for a variety of pests, and overall pest control shifted from a focus on eradication to prevention (Ballard, 2005).

Currently, pesticide use has evolved from general applications of a wide array of chemicals, to recognizing the effects of pesticides upon objects and museum staff, and seeking to turn away from chemical usage--pesticide use in the United States today requires specific licensing and registration with the Environmental Protection Agency (hereby called the EPA) (Goldberg, 1996: 71)

To establish a basis of comparison between IPM and traditional pest management, a typical example of past fumigation methods would be the study involving the analysis of the effects of arsenic and mercury on five items in the Treganza Anthropology Museum collection at San Francisco State University in 1999. The study does not explicitly state the well-documented adverse effects these chemicals have upon human health (e.g. neural degeneration and renal failure from mercury poisoning, or the interference with the electron transport chain of cellular respiration associated with arsenic poisoning), but the implication exists throughout the study.

The Palmer study included a musical instrument, a fossil, cotton packing, debris, and a bag from a drawer where these items were stored. Here, destructive sampling methods (obtaining cut out samples) were employed and a total of nine samples were acquired from these collection items. The musical instrument showed the highest level of contamination with 2.7% mercury by weight detected in the sample. The presence of mercury on the other items demonstrates that mercury was either applied to the entire contents of the drawer and/or migrated to other items.

Such studies conducted on museum collections are indicative of the reasoning behind many museums adopting IPM as a method of pest control without utilizing these toxic pest control methods, instead utilizing an integrative approach that involves many aspects of museum operations to, as the name implies, manage the variety of pests that arise in museums. Moreover, IPM emphasizes an understanding of the biology, ecology, and behavior of these pests, and prevents current and future infestations based upon:

1. knowledge of pest behavior and biology (as previously stated)
2. educating the museum employees on the biology and behavior of the pests
3. proper sanitation throughout the museum (particularly rules against food and drink)
4. application of non-toxic chemicals that can kill or drive away the pests
5. "cultural" methods (ie: rules against bringing food and drink into certain areas of the museum), and:
6. mechanical methods (these are relatively simple, but highly effective preventative measures, such as recaulking the tiles of the interior so that pests cannot get inside the building, plugging leaks in the roof, eliminating of clutter, or even just using trash cans with lids (Jones, 2014).

Collections Management Basics

To properly analyze the museum for the need for IPM, and the processes that our hypothetical small-to-midsize museum should use to manage the pests, museum collections management staff should inspect the surrounding environment in four steps: Step 1 is an analysis of the surrounding environment from the museum's exterior structure for elements that will attract pests, and thus removing these elements from a museum's exterior space elements (an example: ivy and moss upon the exterior of a building, while aesthetically pleasing to the eyes of the museum's intended visitors, are also pleasing to the palate and nesting behaviors of various non-human visitors to the museum, and thus they should be removed); Step 2--Exterior walls and structures should be analyzed as well, because certain materials are more likely to be infested with pest species than others (wood and stucco are much more likely for infestation then brick and concrete, as one might expect); Step 3-Gutters, being reservoirs of water, are also likely to attract various pests (they need water as all living species do); Step 4--The lights of buildings are also an area that needs to be inspected (various species of insect are attracted to light, particularly moths that damage textile-based artifacts, as outlined in Jones, 2014).

One of the major facets of IPM is the aforementioned preventative measures, specifically, being proactive in ridding areas of pests by preventing them from initially infesting, rather than reacting to an already existent infestation. In addition to analyzing the exterior structures of the museum building, as detailed above, measures also have to be taken to reduce clutter and any standing water within the building (indeed, some experts state that offices in a museum shouldn't even have potted plants, due to the watering attracting pests (Jones, 2014). In addition, archival specimens that are not on display are just as capable of attracting pests as those available to the public eye, and preventative measures should be implemented here as well.

Management of the exterior land surrounding the building is also a major facet of preventative IPM. Agronomists and farmers have noted for decades that cultivated fields, which by definition have a regular crop yield, will also have a corresponding regular level of agricultural pests and parasites. While it is unlikely that any museum has a field of wheat growing on its environs, the land still must be maintained regularly to prevent overgrowth and thus pest infestation. In other words, it is reducing the trophic levels of the land to their lowest "potential ecologic threshold", also known as biological carrying capacity; this is essentially reducing the surrounding plant life that can support insect life (Jones, 2014).

One of the core preventative measures is proper care and maintenance of the museum's collections, including housekeeping. A textbook example of this can be seen in the Housekeeping Schedule of the Historical Society of South Australia. The housekeeping document states to "consider the entire space" (Historical Society of South Australia, 2015) of an exhibit collection: the walls, windows, floor and ceilings that surround the object, as well as considering the types of objects being exhibited (various objects have various perceptibility to infestation). It also advises regular vacuuming and cleaning of window sills, but this too varies depending on visitation rates.

Indeed, the majority of this historical society's cleaning space seems to be situationally dependent, but each situation involves thorough and regular cleaning and maintenance, with those objects that are deemed more perceptible to infestation undergoing more frequent care then those less prone to infestation. It goes on to elaborate that certain cleaning substances are prohibited on certain objects (i.e., water is used on display case glass rather than alcohol or other solutions). These regulations are coupled with systematic recording of housekeeping tasks (Historical Society of South Australia, 2015).

Another text, *Museum Registration Methods, 5th edition* (hereby referred to as the MRM, 2011), corroborates many of the above tenets of collections care and maintenance. More specifically, Chapter 5 of this book deals entirely with collections management, and while the majority of it targets concepts of proper handling to avoid anthropogenic damage to collections objects (use of handtrucks, types of gloves to wear for specific types of objects, etc.), Chapter 5, Section G, deals with preventative care and cleaning--not just for pests, but noting that "long term preservation of collections is affected by humidity, temperature, light, and air pollution" (Buck, 2010). The MRM goes on to state that "the components of an IPM program include monitoring, identification, inspection, habitat modification, and good housekeeping…" (Buck, 2010).

In addition to these practices, certain types of pests can be tracked by the use of what are commonly referred to as risk assessments, which are, in essence, the use of decoys that are deliberately meant to be infested, to assess the total population of the area. In particular, these are utilized for termites and other woodboring pests (Carpenter ants, carpenter bees, and other similar species). This is done by the simple concept of creating large boxes or other objects entirely of celluloid or xyloid material (wood, paper, and etc.), and regularly observing it to understand an estimate of the termite population and this population's feeding patterns. Once this information has been obtained, then a plan can be further devised, and the pest treatment that will be used will be decided upon (Jones, 2014).

Once the parameters have been analyzed, and all of the above preventative measures have been performed, there are a variety of traps and extermination methods that can be used for the currently extant pests. Do note that "traps" are mentioned separately from "extermination methods" for a deliberate reason: for insect pests, which are far more common (as well as far more fecund) than vertebrate pests, "traps are used to detect and monitor insects, not to control and eliminate them" (Kingsley, 2001: 63) i.e., the high fertility of insects means that traps cannot possibly catch all of them in an infestation, but it serves to hold samples of the pest species, thus serving to identify them.

The most common type of insect trap is a glue trap, which consists of a pad that has one side with a strong adhesive upon it. This adhesive smells like the preferred food of the desired insect (glue traps are made specifically for a specific family of insects i.e., cockroach traps, fly paper, etc.) They are cheap and fairly effective, but with the highly noticeable drawback of being absolutely repugnant to the aesthetic sensibilities of any museum visitor, with the adhesive pad quickly becoming littered with the corpses of the arthropods.

If adhesive traps are chosen, then the museum curator should consider the possibility to purchase a type that is somewhat more expensive, but which conceals the adhesive from the casual eye, and thus achieving the important goal of not being visually abhorrent to the museum's visitors.

Checklists can be utilized for the preventative IPM measures that were detailed in the preceding pages. One is suggested by the previously cited Chicora Foundation from the University of Nebraska; this assessment splits the monitoring into three segments: the exterior structure, the interior structure, and the records within the monitoring system utilized by the museum. It asks whether or not insects have damaged the exterior and interior, and whether or not there is a floor plan of the facility that marks off areas of potential pest entrance. It also requests to check whether there are cracks in the building structure, or around the doors and windows (Chicora, 2005). The checklist goes onto ask whether or not food waste is distributed throughout the museum, ranges of relative temperature and humidity, identifications of the pest species and life stages they are currently in, the presence (or lack thereof) of vegetation touching the building, the presence of paper trash, and "non-essential lighting" (that will, of course, attract moths).

The second half of the checklist involves "threshold determination," which entails determining policies for pest management within the museum: this part of the checklist is divided into another three sections (define, consider, and educate) (Chicora, 2005). These categories determine such considerations as: how much of a minimal pest infestation an institution willing to accept (in terms of "non-destructive pests"); it asks how much

15. The National Archives (New York Branch), in Syracuse, New York.

damage has been already induced by pest infestation; and asks if there is a formalized consensus from the shareholders of the museum on "pest threshold determination."

From here the checklist asks several related questions, such as the threshold determination specifically for destructive pests (for zero, low, and moderate tolerance), who is the IPM leader/liaison for the institution, the age and adaptability of the infested structures (as they might be damaged even by IPM processes); and staff agreements on structural defects and other issues (Chicora, 2005). The rest of the checklist pertains to methods utilized in both the exterior and interior structure (both non-toxic and toxic), and evaluation, culminating in a sample monitoring chart, which is organized with columns for date, trap number, empty (write yes or no), insect type, life stage, number, and further notes. While this checklist and guideline were created by the staff of the University of Nebraska for use within the university's museum, they intended for it to serve as a general model for IPM programs in all museums and similar institutions, and the thoroughness of it illustrates that this checklist can be used effectively.

Evaluating a storage structure's susceptibility for pest infestation, and determining sources of infestation (such as incoming objects, staff activity, the exterior environment) can explain the persistence of pests around a collection. As it is assumed that there will always be some degree of pest activity (as stated previously), IPM processes focus more upon accepting a (low) threshold of tolerated infestation, at the crossing of which actions should be triggered (and taking into concern relative levels of hazard by species and the material composition of the exhibited object), rather than enforcing a strict "zero tolerance" policy that will impose pest control actions at every least sighting (Strang, 2012).

Newly acquired objects often have the highest risk of infestation. This would hold true even when prior pest control activities have been undertaken on other objects within the collection. Some IPM sources state that it should always be assumed that an exhibited object will be coming from an environment of greater pest infestation than the institution that is now obtaining it, and thus monitoring and inspection should be utilized, and if necessary, pest eradication processes (Strang, 2012). This uncertainty also warrants quarantine until the object is surely devoid of pests.

Quarantine involves two subfacets: inspection and suppression. For incoming and outgoing items, quarantines eliminate all the uncertainties of detection and control methods, and the risk of cross contamination (Strang, 2012). To further lower the probability of pest infiltration, a possible response is to choose to treat all incoming objects, not just suspected display materials. While this can be effective, it also has the adverse side effect of acting as a hindrance to the "flow" of accession (i.e., taking time away from deadlines and other hypothetically pressing issues).

There are several other, more expensive types of insecticides and traps that work via chemical means, with special emphasis upon chemicals that specifically harm the pests without harming either the museum's visitors or the artifacts that are on display. One of the recent developments in these types of procedures are the use of pheromones (chemicals that act as signaling molecules in a silent method of communication), which are predominantly used by insects (although vertebrates have limited use of them as well) in traps that act to bait the pests as a method of entrapment. These are highly effective and most of them are completely harmless to both humans and exhibits. The downside to the pheromone treatments is that they are also very expensive, and being that they are a new technology, not many pest specialists are familiar with their use (Jones, 2014).

Another treatment that is simultaneously highly effective and expensive is the use of quarantine chambers of various types. These chambers are airtight devices that artifacts are placed into and exposed to various conditions that eradicate pests without (hopefully) damaging the objects themselves. These can range from anoxic chambers (chambers that slowly have their oxygen removed to suffocate the pests) to heating and freezing chambers that seek to exterminate pests through obvious means. Research done with Bally Refrigeration (more specifically, the company's Pennsylvania office), which had installed several freezing chambers for the Smithsonian Institute, have revealed that for installation of walk in freezers with a double cycle capability of achieving a -40 degree Centigrade temperature level (required for extinguishing pest infestation), the costs for a 8 foot by 8 foot by 17 foot high refrigeration unit would be upwards to $ 100,000 with installation and electrical costs accounted for (Ballard, 2005). For a small to midsized museum, this upfront cost will be more than likely impractical due to their budgetary constraints.

In 1997, the Canadian Conservation Institute undertook a study of freezing chambers, and the effectiveness therein (Strang, 2012). The study was based on temperature exposure with the goal of achieving 100% mortality for each type of insect tested, based upon exposure times mentioned in entomology literature, and successful treatment logs (Strang, 2012). It was determined through this study that the pests should be exposed to the lowest possible temperatures for the longest possible times, with concerns for not damaging the object itself. Different types of materials were tested to observe the potential damage of freezing: Restored hides showed little cracking or other damage, and neither did painted wood, lamellar materials, or materials that already had cracks. Oil and acrylic paints, on the other hand, did show damage with freezing, and as such these methodologies would be ill advised for artistic collections (Strang, 2012).

The 2003 Carlee Study elaborates further, pointing out several areas of concern such as embrittlement and shrinkage (Strang, 2012). However, condensation, freeze-thaw cycles, and dehydration do not impact objects properly prepared in sealed bags with buffering materials.

The Getty Museum, in Los Angeles, California, found in a study with webbing clothes moths that a weeklong exposure at -30 degrees Celcius (22 degrees Fahrenheit) would completely eradicate the clothes moth infestation, as well as cigarette beetles (*Lasioderma serricone*), carpet beetles, and powder post beetles (Getty, 1994) (Appendix 5). This thorough extermination pattern exists whether the object is put in naked or within polyethylene bags.

In addition to these relatively mundane types of quarantine chambers, there are also much more effective (and more expensive as well) quarantine chambers that operate using "oxygen displacement." Oxygen displacement utilizes gas to eradicate pests, but unlike traditional poison gases, these use noble gases (argon, xenon, neon, and krypton, excluding the radioactive radon) (Greenwood, 2007). The noble gases are filtered into the quarantine chamber and literally displace the oxygen within, suffocating the creatures without any harm being done to the objects themselves. This is in contrast to traditional pest extermination gases that utilize the properties of the toxic chemicals themselves to deal with the pests, and thus these traditional methods are harmful to both the exhibited objects and the visitors of the museum, as has been previously elaborated upon above. Either way, it is understood that obtaining oxygen levels of less than 2% solution are necessary to produce an anoxic environment to kill pests (Greenwood, 2007).

However, current thinking in the field would posit that freezing and heating commit less harm than gas treatments, although, as mentioned above, the noble gases are less harmful than other fumigants. Freezing and heating also have the advantages of having a relatively short cycle of time duration, so that portions of large structures can be treated separately (Greenwood, 2007).

The major drawback of these temperature-related IPM methods is that the temperature must be fully saturated throughout the structure, to reach every facet of the infestation and to avoid "heat sinks" that do not heat fully (the likelihood of this occurring depends upon the material that is being treated, such as tile/ceramic floors, or wooden structures that are infused with concrete) (American Museum of Natural History, 2005).

Heat emitters are a recent invention that claim to spread the heat evenly throughout materials that create "heat sinks," but their effectiveness remains unclear. An analysis of manufacturers and installers of all quarantine chambers (be they heating, freezing, or anoxic) will show that the larger examples of these will be highly expensive--as stated above, the Smithsonian's dual freezing chambers cost upwards of $100,000 (including electrical costs and other expenses of upkeep). While the small to midsize museum may be able to budget in smaller examples of freezing and heating chambers for sufficiently small objects, there is a clear burdensome budgetary expense to be incurred if the heating and freezing units are customized and installed.

A similar dichotomy of size occurs for anoxic chambers. An example of an anoxic chamber for purchase can be found on the website for "In Situ: Museum and Archive Services", located in Thessaloniki, Greece (In Situ, 2014) (Appendix 6). The ZerO2 Set "is a revolutionary method of pest and insect control, using atmospheric methods that make it possible to eliminate insect pests effectively and cost efficiently" (In Situ, 2014). It continues to tout the fact that it leaves no chemical residue or further contamination.

The product description also goes on to explain that this method can be used simply, by in-house staff of one's museum with minimal disruption to the daily activities and labors of the museum: "The oxygen scavenger [the specific name of this particular anoxic device] is based upon the process of oxidation of metal…and involves simply placing the infested object into a relevant container then inserting the oxygen sensors and oxygen scavengers and sealing the bag" (In Situ, 2014).

While this commits no harm to the objects (although some pest controllers have noticed that oxygen scavengers have adverse chemical reactions to Prussian Blue paints and pigments), and is touted as being cost effective, the site admits that the process of oxygen scavenging will take "usually 30 days to complete" (In Situ, 2014). The product description then continues to describe that the "flexitube" bagging can itself be utilized as air-tight storage for museum artifacts. Looking at the various chambers, we can see a trade off between expense, with speed and thoroughness, and being less expensive, while being slower (thoroughness appears to be a feature of commonality between all of the types of chamber-based Integrated Pest control methods).

Preliminary studies on anoxic chambers by (Valentin, 1990) showed that exposure to 1:06:02 atmospheres of an oxygen displacing gas for 20 days killed Death Watch and Powder Post beetles (*Xestobium rufovillosum*). Fruit flies would be killed within 30 hours of exposure (albeit at a 99% nitrogen concentration). Exposure time decreased as the temperatures at which exposures were conducted would increase (in other words, the higher the temperature, the less time of exposure needed). An exposure of 15 days would also kill the woodboring pests that were within this particular pest infestation (Indian drywood termites, *Cryptotermes brevis*), although results are ambiguous for other types of termites (and by extension other woodboring pests), which have different levels of chitin thickness and spiracle placement that may result in differing oxygen absorption rates (Sawyer, 2002).

A case study of a large museum initially using traditional fumigant pest control methods, and gradually converting to IPM techniques, can be seen in analyzing the Pest Management Policy of the American Museum of Natural History (AMNH) (to be more accurate, the Paleontology division therein) (AMNH, 2005). The American Museum of Natural History is one of the premier museums of natural history in the world today, and in light of this, its IPM procedures will be discussed below.

While the AMNH was, since its inception, a pioneer in taxidermy and initial preservation techniques, this museum used the typical pest prevention methods of the early-to-mid 20th century. The pest policy clarifies that fumigants worked to clear pest infestations from museum object displays, but with the danger towards human visitors being clear, they sought alternative means; as mentioned above, noxious chemicals like arsenic and mercury were used for pest control throughout the early 20th century. In addition to ending the use of contaminants, the AMNH has also made efforts to clean objects that have already been inadvertently contaminated by these primitive pest control methods, particularly, and for obvious reasons, objects repatriated to American Indian tribes via NAGPRA (AMNH, 2005).

The AMNH policy goes on to explain its process: it establishes a need to sample artifacts in a composite way to determine contamination levels, not just on the surface of the object, but integrated within the substance of it as well, and communicate with non-scientific departments of the museum to develop a swift response and goals consistent with AMNH safety regulations and the federal Occupational Safety regulations. The policy identifies the typical patterns of pest infestations that are observed in the process of museum accessions and acquisition: various types of pests that will attack labels (wood-boring pests such as termites and carpenter beetles), padding materials (clothes moths, webbing moths), and drawers or cabinets (also preyed upon by wood boring pests) (AMNH, 2005).

The steps of the AMNH policy are: 1) containment of the building (doors, windows, and cabinets that are infested; 2) Preliminary environmental procedures (lowering or raising the temperature and/or humidity based upon the needs of the infestation at hand); 3) Contamination controls (putting objects in separate collections areas to avoid further cross contamination, and inspecting for further contamination, both between exhibit objects and in new accessions to the museum collection; 4) Monitoring and elimination of the current infestation, and the use of techniques for deterrence of future pest infestations (AMNH, 2005).

The fourth stage of monitoring and elimination is split into further steps of action: traps are strategically placed, and also recording of data is utilized. Before any traps, are placed, the policy specifies that objects are sprayed with "Tempo," a commercially available pest control substance that claims numerous benefits upon its website, including the power of powder formulation in a low-toxicity liquid. The website further specifies that it works upon the emerald ash borer (*Agrilus planipennis*), a recent invasive species to the United States.

Beyond Tempo, the AMNH uses freezing for pests that the Tempo spray cannot reach for whatever reason, and uses Napthalene (another pesticidal chemical, somewhat toxic to humans only after prolonged exposure) within cabinets.

Shipping and handling procedures (in other words, preventative IPM techniques,) are also specified in the AMNH policy guidelines (AMNH, 2005). Any incoming shipment will receive a full and thorough inspection before they are moved into the exhibit halls. The crates and packaging material should be analyzed to an equal degree as the actual acquisitioned objects are. "Common sense" methods are utilized, such as opening crates one at a time, and inspecting each, before moving onto the next one (to avoid cross contamination, of course). The packaging materials are then put into heavy grade storage after being cleaned (sealed and duct-taped garbage bags are used for this packaging material) (AMNH, 2005).

Beyond this, food is not left in the office overnight, cleaning is done regularly, and other sorts of "common sense" techniques are utilized. The AMNH's IPM policy can thus be said to be similar to those of other large museums around the world. Another large museum to analyze is the National Museum of the American Indian, an affiliate of the Smithsonian Institute, hereby referred to as the (NMAI), which greatly utilizes IPM, in particular having a specifically outlined procedure for handling of food within the museum (Ballard, 2005).

In the NMAI, food is only allowed in the museum café, or designated areas for special events (Ballard, 2005). No school tours that bring lunches are allowed in the building. Food and beverages are not allowed in NMAI galleries, basement offices, work rooms, or public elevators. Trash is cleaned and carted out of the museum daily. In addition to the specifically enumerated food policy, the NMAI also has a clear, general purpose IPM policy:

Moldy objects are put into a Tyvek envelope (a polyethylene fiber), to avoid cross contamination. Employees are instructed to move the envelope as little as possible to avoid spreading the mold. Mold is then removed through the use of anti-fungal chemicals and dried via the use of heat (with the exception of wooden objects, as drying will split the wood) (Ballard, 2005).

Another study that supports the above analysis of the NMAI can be observed in the Detroit Historical Museum, for an example, of how damaging mold can be for exhibited objects. The summer of 1995 had record-breaking heat and humidity in Detroit, Michigan, which negatively affected the storage facility. Compounding this was the chief engineer being ill, and the consistent 90% humidity led to 51,000 artifacts being fungally infested. Budgetary restraints further impeded fungicidal remediation efforts, and after the available staff efforts were completed, it was found the project had been budgeted for a shortfall of hours in the budget (more specifically, it was roughly 25,500 hours short in projected manhours of labor to completely remove the mold) (Dicus, 2000).

An even more effective method of IPM and requiring less labor hours than the aforementioned Detroit example is to evaluate further how the NMAI went about exterminating live pest infestation. The NMAI is inclined to use more technology such as freezing (Ballard, 2005), and their reasons for doing so are enumerated: 1) The use of freezing avoids the concerns that fumigant pesticides bring; 2) The treatment time is faster than other methods; 3). It requires relatively few staff members present; 4) The method is cost efficient for their collections in the long term (the freezer is initially expensive, but it needs no expenditures beyond occasional upkeep). However, bear in mind that the NMAI is an affiliate of the Smithsonian, a large museum with a large budget.

The medium size museum's IPM policy can be seen as similar in its statement of purpose to the large museum, even though it is smaller in design, and for this case, this thesis uses the Minnesota History Museum, hereby referred to as the (MHM), as a template: their IPM goals are not as specific as the AMNH's, mentioned above, but this can be seen as advantageous (if only because it avoids confusion)--their pest control goal is simply stated: "keep facilities free of pests" (Minnesota History Museum, 2008) (Appendix 7), which itself consists of three steps--1) monitoring of incoming exhibit objects to observe preliminary pest infestation; 2) building maintenance (both interior and exterior); 3) Housekeeping (another act of proactive pest prevention); 4) Eradication of pests by various means, up to and including chemical pesticides in extreme cases.

In the event that an infested object is accessioned into the museum, they are held in pre-treatment Quarantine chambers: the object is bagged and wrapped near the loading docks (wrapped in polyethylene) (Minnesota History Museum, 2008). The Conservation

Department will then decide on a fumigant to use (if it is a large object), or it will be frozen (if it is small enough to fit in the freezer).

Just as referenced above, objects that have mold have their own process of control (mold not being considered a "pest" by the definition that this thesis has used throughout its body i.e., an animal). Moldy objects are brought into a specifically designated "mold room" (to avoid cross contamination), the object is treated with a fungicide, and the object is then dried by conventional means (Minnesota History Museum, 2008).

For all objects, regardless of the type of pest infestation, after procedures have been used, objects are moved into exhibit spaces with other collections. If fumigants are used, safe handling techniques are stressed, and the treated objects are monitored for reoccurrence. Special pest control techniques are also stressed for paper based collections (archives, documents, and the like). Paper, when found to have mold, is put in plastic bags and later cleaned, as other moldy objects are. When animal infestation is observed, the object conservator moves boxes to the museum collections quarantine area (Minnesota History Museum, 2008).

The staff sends delegates to attend yearly IPM conferences, and further methods of educating the staff in this topic are used, such as collecting samples of live insects, mandatory classes within the MHM itself (training the staff in pest knowledge, proper handling of objects, applications of traps and housekeeping, etc.) (Minnesota History Museum, 2008).

The MHM pest policy, to be expected, has a section pertaining to live pests: The first step is monitoring: if there is a live infestation, notify the object conservator or site curator immediately. Second, if the object is on loan, contact the Central Register. Third, a common sense measure, the museum employees are specifically told to not kill pests on their own (i.e., do not swat or stomp upon pests, due to the risk of damaging the object). Pests are then identified, and a plan of extermination is decided upon. The last step before the process of extermination is isolating the infested objects in heavy duty polyethylene bags (Minnesota History Museum, 2008).

Treatment of objects is similar to the large museums: freezing, depending on the size of the object, is used for most insects, and for smaller objects. However, for larger scale jobs, fumigation is utilized (Minnesota History Museum, 2008).

Common Museum Pests

Having given an overview of common IPM methods, this thesis will now outline the common types of pests that can globally be found in museums, of which there are several. Identification of pest species and the current instar (life cycle) of the pest species "are the core of any IPM plan" (Chicora, 2005). Correct identification allows one to distinguish whether a species is dangerous to the collections or not, an estimate of the degree of infestation, how long the infestation has existed, and ultimately what measures will reduce the presence of particular pests. Identification can be difficult, but there is an abundance of entomological literature in existence (both in hard paper copy and the internet), which can help the difficult task of identification.

One of the most common (speaking generally for human civilization, but also for museums specifically) are woodboring pests. These are especially prevalent in museums due to the prevalence of wooden artifacts and cellulose materials (such as paper) in these institutions. These woodboring pests eat through these artifacts and materials in addition to the underlying structure of the buildings themselves (Chicora, 2005).

Woodboring pests contain three large divisions within the broad category: termites (infraorder *Isoptera)*, wood beetles (of the order *Coleoptera,* also referred to as post beetles or furniture beetles), and woodboring *hymenopterid*s (the various species of carpenter beetles and carpenter ants), the latter of which for the purposes of this thesis can be seen as similar enough to the termites that similar treatments can be used.

Termites

Termites are often confused with the latter hymenopterids: both of them form eusocial hive systems (rigid caste systems triggered by hormonal effects), but termites are actually closer related to cockroaches (and are thus found in the order *Blattodea*) then they are to ants or bees, as can be judged by genetic analysis (Pest Control US, 2012) (Appendix 8). Nor, for that matter, are termites related to true mites (mites are arachnids, while termites are hexapod insects). Termites typically feed upon decaying plant material, found in a variety of sources (free-standing dead wood and leaves, or cellulose within the dung of other herbivorous/folivorous animals). The rather complex caste system of the typical termite hive is as follows:

The core of the hive is of course the queen, and she (contrary to the fantastical depictions of the "hive mind" seen in fictional works) largely exists for one vital purpose: reproducing (with a secondary purpose theorized to be pheromone release that aid in colony integration and other signals). In fact, all of the eusocial insects are characterized by, among other things, the queen being the only female that is capable of giving birth. The queen is the most notable of all the termites, due to her enormous abdomen that heavily restricts her movement (necessitating attendant workers to carry it for her) but this anatomical feature enables her to lay thousands of eggs daily. Unlike other eusocial insect species, termites have kings that fertilize the eggs and mate with the queen for life (up to 45 years in some species), rather than the multitude of drone fertilizers that bees and wasps utilize.

The winged caste (called "alates" or "swarmers"), are the only termites that have well developed eyes, as it is their primary duty to find sources of food and water (more accurately, they like moist surroundings, as they absorb most of their water through their thin bodily cuticles). The amount of surrounding moisture that is necessary varies depending on which species of termite one is discussing. Termites are for the most part weak fliers; the swarmers of some species (roughly 4000 species total) do not even have wings. In the event of a queen dying, swarmers may be recruited by the hive (via the use of pheromones) to be the new reproductives (i.e., turning into a king and queen) (Pest Control, 2012) (Appendix 8).

Soldiers are, as their name implies, primarily tasked with protecting the queen (the sheer reproductive potential of the termite monarchy means that workers and swarmers are capable of being sacrificed in great numbers). They are characterized by their oversized mandibles, adapted specifically for purposes of fighting ants, the primary threat to termite hives (a few termite species have more specialized methods of combat, ranging from oral spraying of noxious and toxic chemicals, to deliberately exploding themselves and spraying toxins upon invaders). Their mandibles are so massive that they are, in fact, incapable of feeding themselves, and must be fed by worker termites, the most common caste (Pest Control, 2012).

The workers undertake the bulk of the hive's necessary labors: foraging (once the swarmers have found food sources), food storage, hive maintenance, and in some species auxiliary defensive duties like tunnel maintenance (for the purposes of creating phalanx-like defensive perimeters for the soldier termites to fight the more agile ants upon an equal footing). They also digest and excrete cellulose (through the use of prokaryotes within their digestive tracts) so the rest of the colony can ingest the nutrients. The holes that termites dig in irregular burrowing patterns (in contrast to other wood-boring insects that are discussed later in this thesis, that are capable of digging with the grain of the wood) are the beginnings of long-term colonies, which are also in marked contrast to the uniform burrows that other wood-borers create that are largely incubators for their pupating larvae (Pest Control, 2012). As mentioned elsewhere in this thesis, termites are the pest group that causes the most damage for humanity in general, and museums are certainly to be considered as a target in this regard.

Termites are generally grouped based upon their feeding and nesting behaviors: some are subterranean, and some are differentiated by the types of material they eat (dampwood, dry wood, or grass). Despite the names, all termite species feed primarily upon celluloid materials, as stated above (a necessary part of the carbon cycle, putting organic and inorganic nutrients back into circulation in the biosphere) (Pest Control, 2012). Each type of termite can be further classified based upon its relation to humanity, and by extension, to human-made structures.

The termites that primarily act as pest species for humanity are the subterranean and drywood termites. Subterranean termites are commonly found throughout the world, not just the large mound building ("termitaria," to be technical) species that are commonly associated with the Old World tropics (Constantino, 2008). In fact, the Eastern Subterranean Termite (*Reticulitermes flavipes)* is the most common species of termite in North America, and does the most structural damage of all the termite species on the continent as well, particularly damaging small museums and historical/landmark houses (when compared to other museums and public institutions). This species is classified by workers and swarmers being wingless and white-bodied (more accurately, swarmers lose their wings after finding a suitable nesting ground). These termites, favoring dry wood and other dry cellulose material, are responsible for 80% of the roughly 2 billion dollars ($2,000,000,000) spent upon termite control in the United States every year (this figure encompasses all termite control, not differentiating between private homes and museums, as outlined in Beccaloni, 2013: 12).

Dry wood species in the United States (not including the Eastern Subterranean Termite that is referred to in the preceding paragraph) such as *Incsiitermes minor*, which is the most numerous drywood termite in the United States, are characterized by red chitin (chitin being the non-cellular substance that various invertebrate exoskeletons are composed of) and black wings, in stark contrast to the typical termite morphology that will possess either white or black chitin and white wings.

A preliminary scan of the wooden object can reveal whether these sorts of dry wood termites are infesting the structure: dry wood termites and subterranean termites excrete a dry powder comprised of urea, known as "Frass," that is associated with their nests (in contrast to this, many other species leave a uric acid paste, as do many other unrelated species of insects).

As alluded to above, there are basic preventative measures that can be taken to minimize termite infestations before they occur: the most notable is, of course, to not build using untreated wood; varnish and other chemicals act as noxious preventatives that repel woodboring insect infestations. In general, termites seem to go out and probe for sources of food in the early spring (March/April), so any preventative measures that would be utilized would have to be done in months prior to this emergent period, to circumvent the swarming behavior of the termite hive and prevent infestation.

Once termite infestation has been identified, obviously the preventative measures will be ineffective at this point. At this point, one can utilize the process of risk assessment that was discussed in a section above, i.e., cellulose structures kept away from the actual integral structures of the museum, and observation of the damage done to it/the termite hive's feeding patterns. In fact, these risk assessments work best upon woodboring pests, as the damage they cause is much easier quantified than other types of damage (due to the fact that furniture and wooden structures already have monetary value affixed to them).

After risk assessment and identification, there are several methods of controlling and reducing infestation: the traditional manner is gassing, which is, of course, effective in removing pests, but with the downside of necessitating evacuation from the building of all human visitors (for extended periods of time), and contains the risk of damaging both the material held within the museum collections and the visitors within. A typical example of these is the chemical sulfuryl fluoride, which several resources point out are not capable of being purchased for homeowners, and it is recommended that professionals be hired specifically to apply this noxious chemical (Pest Control, 2012) (Appendix 8). This chemical will kill drywood termites quickly and almost entirely, but as one might expect it possesses the same risks that other poison gases have: namely risks to people and property (Constantino, 2008).

A process that is less harmful and equally effective (albeit more expensive and rare than traditional methods) for some termite species (the underground species, to be more specific, including the Eastern Subterranean Termite detailed above) are underground termite baiting chemicals and capture systems that utilize pheromones mimicking the termite hive's natural signaling chemicals to neutralize the hive (Pest Control, 2012). More accurately, these chemicals target only the foraging workers and swarmers, essentially signaling them to not engage in these behaviors, which slowly results in the hive starving to death (Constantino, 2008).

Heating treatments can also be used upon termite infestations, somewhat counter-intuitively (as most would not associate heat treatment with benefiting wood). This involves putting the wooden objects in a heating chamber at a temperature between 120-200 degrees and holding it in this temperature for a period of an hour or more.

In addition to these approaches, there are other types of IPM-approved pest control devices: one is the use of a technique that has been dubbed "organic pest control" (Cranshaw, 2005). This is a broad spectrum of pest control tools that are already of familiarity to organic gardeners and similar hobbyists: introducing predatory animals that feed upon the pest species. In the case of termites there are parasitic nematodes that can be used, that prey upon the termites and of course prevent further propagation of the termites. Another benefit of this method is that, due to the nematode family being microscopic roundworms, they are completely unnoticeable to the museum staff or visitors.

Woodboring Beetles

Woodboring beetles, in contrast to the termite, are a wide range of species, genuses, and families of beetles that are characterized in some fashion by the ingestion of wood and other cellulose materials (Cranshaw, 2005). Species vary as to whether the larval or imago (adult) form of the insect is the one that actually performs the ingestion therein. Of this variety of species, the three most common are longhorn beetles (*Cerambycidae*), bark beetles (also known colloquially as weevils and scientifically dubbed *Curculionidae*), and metallic flat headed borers (*Buprestidae)* (Cranshaw, 2005). They are not eusocial species as the termites are, and as such their overall analysis in this paper will not be as long as those of the termites.

Most woodboring beetles are relatively benign ecologically (in the sense that they feed upon dead or dying trees with notable signs of rot or decay and are thus important factors of the carbon cycle, serving as decomposers), but while they do not have the same degree of deleterious effects upon the lumber industry, museums and landmarks, and home construction that the far-more numerous termite species do, certain species of woodboring beetles are notable pest species by attacking living and healthy trees (such as the Asian Longhorn Beetle, *Anoplophora glabripennis* and the aforementioned Emerald Ash Borer), as well as other species feeding upon lumber used in human construction projects (Sawyer, 2002) (Appendix 10).

The typical woodboring beetle does not spend its entire life cycle residing within wooden structures, instead merely burrowing into the shallow sapwood, depositing its eggs within burrows and allowing the larvae to feed upon the xyloid material. In general, the woodboring beetles prefer damp wood (giving equal preference to hard and soft wood) (Sawyer, 2002). However, it is worth noting that the two most destructive species of woodboring pests, the Asian Longhorned Beetle and the Emerald Ash Borer (both species non-native to the United States) feed almost entirely upon living trees (Sawyer, 2002), and while they are a grave threat to such entities as the National Parks and the timber industry, they are not, at the present time, of immediate danger to museum collections (Sawyer, 2002). However, other woodboring beetles (such as the aforementioned Powder Post beetles) are still a threat to exhibited objects.

Generally speaking, woodboring beetles are detected a few years after construction, when the next generation of beetles emerges from the burrows that their parents had dug for the larvae. They are more common in areas of high humidity; as mentioned in the last paragraph, woodboring beetles prefer damp wood to dry wood. As with other pests, fumigants are an immediately effective option for eradication of pests, with the attendant environmental and physiological issues that fumigants tend to bring. Heating and freezing chambers are a viable option for the control of woodboring beetles instead, with the similar issues of time and budget needing to be considered as was discussed in previous parts of the paper.

While most woodboring beetles prefer living wood, a few prey upon household construction and furniture, and as such, these are the ones most associated with museum pest control: the common furniture beetle (*Anobium punctatum*), the powderpost beetle (Genus *Lyctinae*), the Old House Borer (*Hylotrupes bajulus*), and the Death's Watch

Beetle (*Xestobium rufovillosum*) (Sawyer, 2002). All of these can be treated in the same way (detection via frass and burrow holes, and dtreatment via heating and freezing) (Cranshaw, 2005).

Cloth Eating Pests

Of equal concern to the museum employee are the cloth eating pests (various types of beetles, moths, and other insects that eat cloth, furs, and other soft materials commonly held in museum exhibits). There are numerous examples of these, but the two being profiled here are the webbing clothes moth and the carpet beetle, both of which have become invasive species throughout the world and thus are of high concern for the museum:

The aforementioned Webbing Clothes Moth acts as a pest in its larval form: ingesting and excreting various soft, fibrous materials for the purposes of making its chrysalis and undergoing metamorphosis (Cranshaw, 2005). This insect is unique due to its ability to gain sustenance and nutrition from keratin proteins (a protein found in fur, hair, feathers, silk, and other natural fibers that are inedible for most animal species)

The adult females of this species lay eggs in large clusters of 40-200 eggs, ensuring the propagation of the caterpillars throughout the immediately surrounding environment. Unusually, studies seem to indicate that the adult females prefer fabrics that are soiled compared to those that are clean for ovipositioning. Although it is not specifically known why this is, it is thought that traces of dirt and moisture are nutritional supplements for the larvae (Jackman, 1998). In addition to this, both larvae and adults prefer dark conditions, in contrast to other moths that are attracted to light.

These caterpillars are nearly microscopic, and largely will not be noticed until the cocoons have already been spun. This larval stage lasts between one month and two years (depending on conditions), and adults will then live for an additional month before laying eggs and dying (the adults do not feed at all, having gained all of the nutrition they need from its larval ingestions (Jackman, 1998).

The allusion to "favorable conditions" in the preceding paragraph belies one of the major methods of controlling these pests, which are of course heating and freezing chambers. Webbing clothes moths prefer a range between 40-75 degrees Fahrenheit (10-24 degrees Celcius), and thus it does not require a particularly large expenditure of energy to create conditions fatal to the moths (Jackman, 1998). In addition to these, several of the "common sense" methods of pest control can be effectively used to control these moths: air tight containers will prevent reinfestation, exposure to bright light combined with brushing will dislodge any larvae that are already infesting the material, dry cleaning the infested material, anoxic chambers, and vacuuming.

In addition to these non-chemical methods, mothballs in concentration will kill larvae on contact, with the drawback of paradichlorobenzene (the active chemical in moth balls) being toxic if ingested. This is, however, less harmful than the arsenic compounds, camphor, and chlorinated hydrocarbons that were used as anti-moth methods up until the latter half of the 20th century.

Biological methods of pest control can also be utilized to varying effects: red cedar and lavender oils have a moderate degree of effectiveness upon moth infestation, with the disadvantage of giving exhibited objects a distinct (and perhaps unwanted) odor. Even more unusually, parasitic wasps such as the *Trichogrammatid* genus are advocated by some pest control groups (they lay their eggs within the moth larval clusters, where the wasp larvae will then feed upon the moth caterpillars). These wasps are tiny, measuring only about 3 millimeters (or .1 inch) and thus are non-harmful to humans (Morse, 2010) (Appendix 11).

Carpet Beetles

Carpet beetles, also known as the *Dermestid* genus are a family of about 500 species worldwide that are characterized by being scavengers, feeding upon dry animal or plant matter (skins, hair, feathers, and natural fibers, among other substances) (Sawyer, 2002). In fact, these beetles are used constructively by museums to clean animal carcasses. However, they can quickly become uncontrollable and harm any exhibited objects that are made of soft material.

The larvae are easily recognizable due to their characteristic setae (hair-like extensions of their chitin) and rotund shape. Unlike the webbing clothes moth, the various species of carpet beetles ingest substances both as larvae and adults, although the larvae do more damage than the adults (Sawyer, 2002).

Despite the fact that there are hundreds of different species of *Dermestid* beetles, control of these can largely be divided into either hide (also called larder) beetles, and carpet beetles. Both can be largely handled with proper housekeeping procedures and other "common sense" methods, as well as freezing (at 0 degrees Fahrenheit or -32 degrees Celsius) and heating (at 120 degrees Fahrenheit, or 34 degrees Celsius) already infested objects (Sawyer, 2002). The major difference is what objects have to be of concern for each type of beetle: larder/hide beetles must utilize airtight containers for food and organic materials, whereas airtight containers can be used effectively for clothes or other cloth materials to halt the carpet beetles. Diatomaceous sediments (meaning sediments that have a high presence of silica originating from microscopic organisms) can also be used to ward off dermestid beetles, but for obvious reasons (namely, sediments later need to be cleaned up) this should be used with caution (Cranshaw, 2005).

Cockroaches

The highly ubiquitous group of insects known as the cockroaches (biological order *Blattodea*) are an order of pests that are known to all people around the world, wherever sedentary human societies are found. Although they are more associated with larders, pantries, and other storage of foodstuffs, they are commonly found in museums, particularly those that have cafeterias or other dining areas.

Although there are roughly 5,000 species of cockroach, only 30 of them are associated with human settlement. The four most common pest species are the American cockroach (*Periplaneta americana*), the German Cockroach (*Blattella germanica*), the Asian cockroach (*Blattella asahinai*), and the Oriental Cockroach (*Blatta orientalis*), often called the waterbug to avoid confusion with the aforementioned Asian cockroach (Tilyard, 1937: 24).

Each species is distinct (in terms of coloration, gloss, antenna shape, wing shape, size, and function), but there are many similarities that characterize this biological order: They are highly cosmopolitan, living in almost all types of environments on Earth but preferring warm conditions (meaning they are likely to invade buildings). The vast majority are nocturnal, and prefer darkness to light. Most species are also characterized by setae (spines) on their legs that aid in vertical locomotion. They are, for the most part, solitary insects, but their feces (which forms dry frass similar to the termites) have recently been found to have pheromones in them that mark sources of food, water, and other resources. This seems to show that cockroaches are capable of swarming behavior, albeit to a lesser degree than the eusocial insects (Hamasaka, 2005). Most species possess wings, although many only have vestigial wings and are thus incapable of flight.

In general, cockroaches are omnivorous, opportunistic scavengers (with the exception of a few woodboring species that of course eat solely cellulose products). They breathe through spiracles and trachea tubes, as many insects do, and their breeding methods typically involve exterior egg cases attached to the females, although a few species in fact give live birth (Daly, 1998)

As a group of pest species, cockroaches are associated with many adverse effects upon humanity: they feed upon food stores, passively transport microbes and bacteria through their body surface, and their frass and shedding are allergens that can trigger asthma attacks (Kang, 1979: 382).

This order is famously hardy (their threshold for radiation poisoning being 10 times higher than the average human, and some species being capable of surviving decapitation for several hours), and due to their sheer tenacity (being capable of surviving a month without water and three months without food), infestations are more difficult to eradicate from an area than some other pests. However, cockroaches are ultimately capable of being exterminated, just as any other pest is. As with the other common types of pests enumerated above, there are many preventative measures that can be utilized to prevent initial cockroach infestation: food and water should, as always, be kept in sealed, airtight containers. Garbage cans should have lids, and surfaces should be regularly cleaned and vacuumed. Water leaks should also be repaired, as standing pools of water attract thirsty cockroaches. Entry points should be sealed off as well (drywall repairs, recaulking, repairing baseboards and windowpanes, etc.)

Similarly to the Dermestid beetles, diatomaceous sediments can be used to kill cockroaches (via dessication of the cuticle layer of the insects) (Quarles, 1992) (Appendix 13). Biological control is of subjective effectiveness: while the cockroach has several natural predators (such as hatchet wasps, family *Evanidae*, and the house centipede, *Scutigera coleoptrata),* the effectiveness is compromised by the fact that most people would likely find the predators to be almost as objectionable as the cockroaches themselves.

Sticky traps are also effective in attracting and trapping cockroaches, with the drawback of being repugnant to the observer. There also, of course, various pesticides that can be used. In addition to these, an inexpensive cockroach trap can be made with the use of a smooth-walled jar, some food bait, and vaseline lining the inner walls of the jar- place the jar somewhere that allows for easy access (such as next to a wall), and wait for the roaches to go for the bait inside. The vaseline insures that they cannot leave the jar once they have entered.

Collections Management and IPM Issues in Historical Collections

As alluded to previously, historical collections in particular are greatly attractive to pest infestations.

As the Minnesota Historical Society outlines, practical care for the care of collections can be outlined in seven general areas: Basic Preservation Considerations; Storage Containers, Supports, and Mounts; Storage Furniture; Handling Practices; Cleaning Practices; Display; and Materials (Minnesota Historical Society, 2015) (Appendix 9). In describing the last category, Materials, the following point, especially relevant to historical collections, is made:

"The unique characteristics and specific needs of particular materials or groups of similar materials…[are adapted from] standard practice to meet the needs of particular items depending upon their composition. For example, does a collection of wooden furniture have special temperature and relative humidity needs? Or, are there particular concerns regarding insect infestation for leather clothing items?" (Minnesota Historical Society, 2015).

The MHS website seems to verify the necessity of IPM for historical collections, as it specifically notes types of materials susceptible to infestation: paper, skins, textiles, wood, quills, horns, antlers, shell and bone. While the basics of integrated pest management do not differ greatly depending on the type of institution, historical collections do have special considerations, largely due to the materials on hand in these heritage institutions, leading to a higher prevalence of pests in historical collections than, for example, a geological exhibition.

Another useful source that focuses on pest-related issues involving historical collections is published by the Northern States Conservation Center (hereby referred to as the NSCC). This institution, which largely serves to train other museums in collections care and pest. Called "Pest Management in Museums, Archives, and Historic Houses," the publication emphasizes the necessity of IPM for historical collections and outlines recent developments in IPM in the heritage sector (Pinniger, 2001). Moreover, the book argues that IPM is safer and more cost-effective for heritage institutions as compared to traditional pest control methods.

Finally, as a statistical analysis of the conditions of collections in all museums across the United States, the aforementioned Heritage Health Index (HHI, 2004) does not make recommendations stating which pest management practices are better. However, the HHI emphasizes that history museums need to take efforts to preserve the close to 1 billion photographic or other historical collections they house. The HHI also indicates that the majority of museums do not have dedicated pest controllers, but instead, that they use various staff as needed. While the organizations indicated that and this was satisfactory for their purposes, it is important to note that 31% of institutions reported that there had been some degree of damage from pest infestation, while 2% reported “significant” damage. Although 65% of the respondents here were archival organizations, historical societies were stated to have the greatest "urgent need," at 17% (HHI, 2004).

With the overview of the basics of IPM and common types of pests in the modern museum completed above, the results of the survey conducted for this thesis will be presented next, followed by a discussion of the results of the survey. Finally, several conclusions and recommendations will be presented.

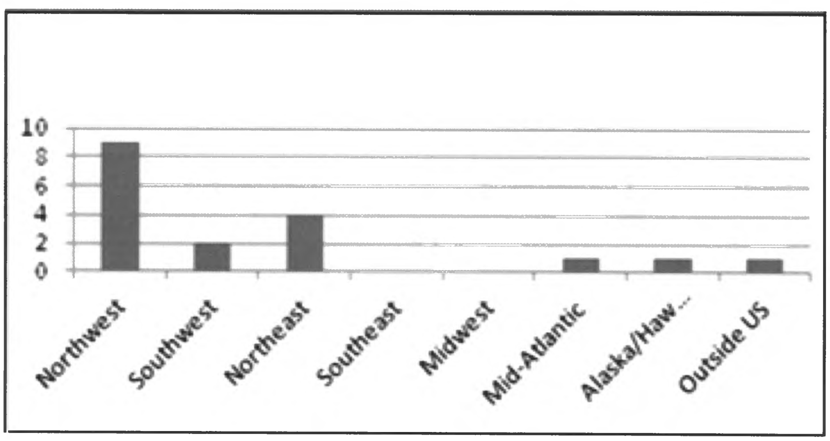
Chapter 4: Results

In this chapter, the results of the survey will be presented. After a review of the overall response rate, the results of each survey question will then be outlined, along with a series of tables that depict the results graphically.

As outlined in the last chapter, 95 surveys were distributed to museums in North America. Eighteen museums responded, representing a response rate of 19%. Notably, every one of the museums surveyed filled the survey out to completion. As a result, in the section below, all percentages outlined will be based on the 18 responses received.

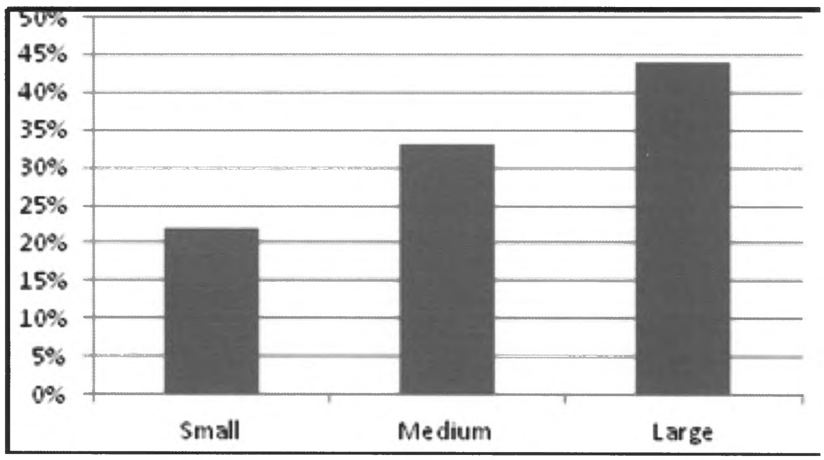
Question 1a asked which region of the United States the museum resided in. The options were the Northeast, the Southeast, the Midwest, Southwest, the Northwest, Mid-Atlantic, and Alaska/Hawaii. Of the 18 results, 4 were from the Northeast (22.2%), two were from the Southwest (11.1%), 9 were from the Northwest (50%), one was from the Mid-Atlantic region (5.5%), one was outside the continental United States (Hawaii, specifically), and one was from Canada (Table 2).

Table 2: Geographic Region of Respondents



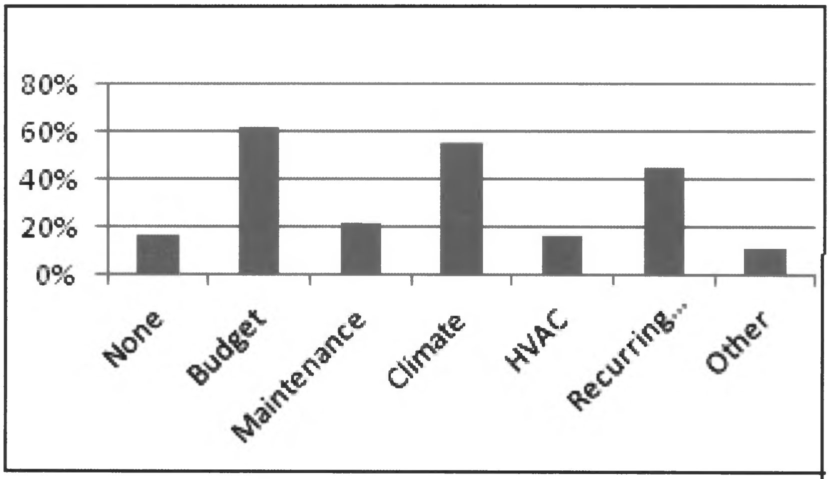
Question 1b asked about the approximate size of the museum's collection: the options given were small (less than 10,000 objects), medium (10-50,000 objects), and large (50,000 objects). Of the results, 4 were small museums (22.2%), six were medium-sized museums (33.3%), and 8 were large museums (44.4%) (Table 3).

Table 3: Percentage of Museums By Collection Size



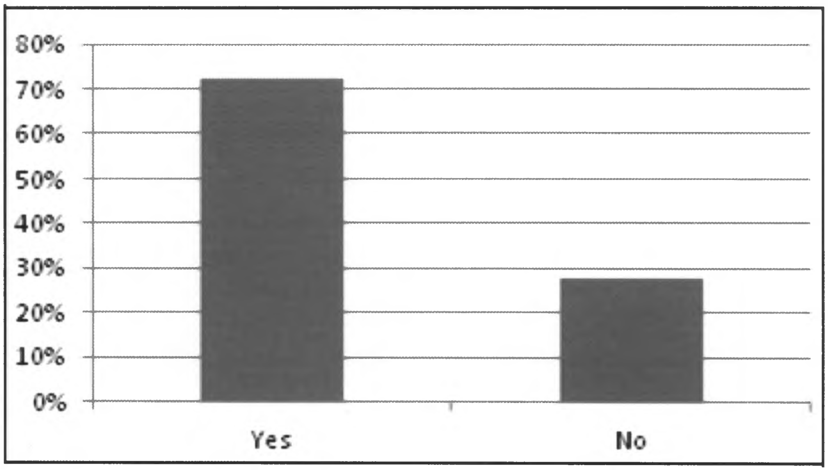
Question two asked which IPM issues the museum has encountered: the options offered were building structure maintenance, internal climate control, infestations, insufficient budget, no modern HVAC systems, or other (a blank space to fill in). Of the surveys, three had no issues at all (16.6%), 11 had budgetary issues (61.1%), 4 had maintenance (22.2%), 10 had climate control issues (55.5%), three had HVAC issues (16.6%), 8 had recurring infestations (44.4%), and two had non-specified others (11.1%) (Table 4)

Table 4: IPM Issues Encountered



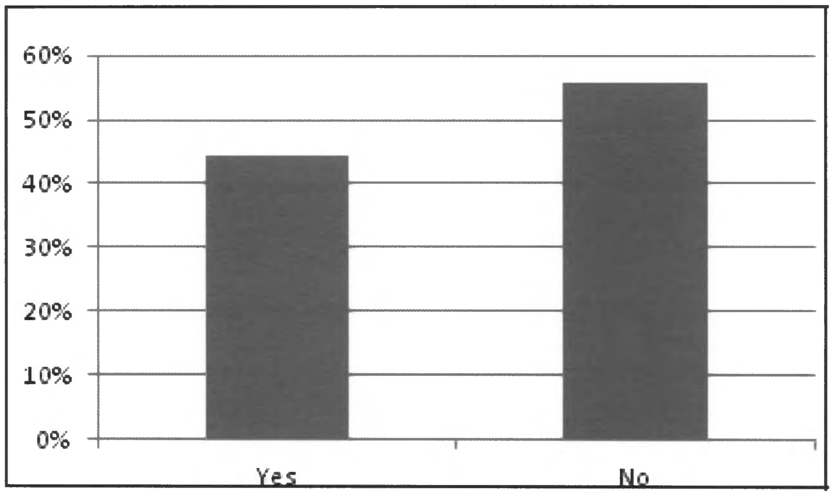
Question 3 asked about the IPM plan used: 3a asked if the museum in question utilizes a formal IPM plan, with the possible answers of yes and no. Thirteen museums had a formal plan (72.2%), and five (27.7%) did not (Table 5).

Table 5: Presence or Absence of Formal IPM Plan



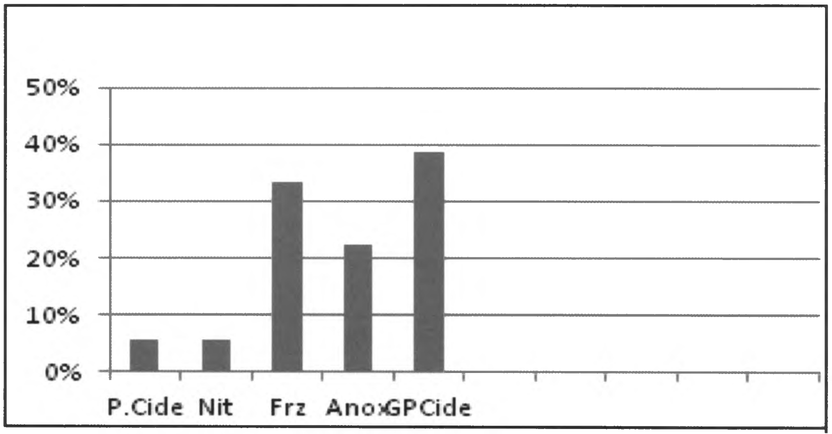
Question 4 pertained to prevention, asking which preventative measures the museum used for its pests (4a), and whether or not the museum had designated quarantine zones for infested objects (4b). Responses for 4a included the following: good housekeeping (which was cited by almost all of the museums), segregation of infested objects, and inspecting the museum for points of pest ingress, among others. For question 4b, 8 had designated quarantine areas (44.4%), and 10 did not (55.6%) (Table 6).

Table 6: Presence or Absence of Quarantine Areas



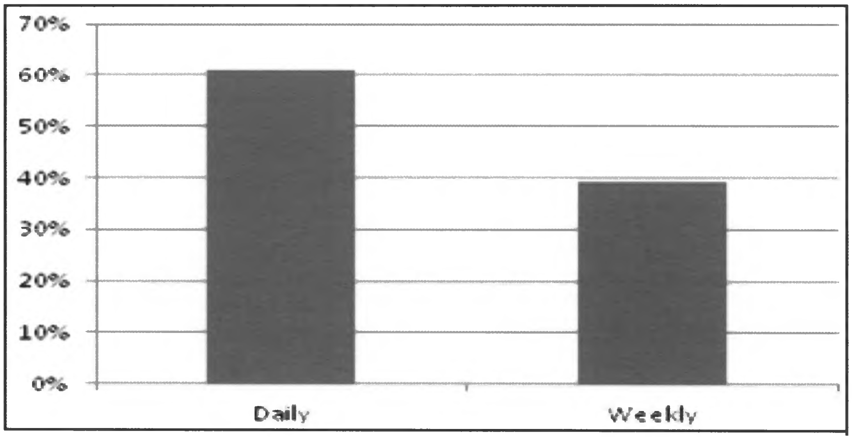
Question 5 asked about the treatments used for pests: the options given were pesticides, CO2, Argon, Nitrogen, Heat, Freezing, Anoxia, and Green Pesticides. Of these, 1 used conventional pesticides (5.5%), one used nitrogen as an anoxic agent (5.5%), six used freezing (33.3%), four used anoxia (22.2%), and seven used green pesticides (38.8%) (Table 7). It is worth noting that several museums use more than one method, and many other museums wrote in that they used none of these, but vigorous monitoring and inspection were sufficient in keeping pests away.

Table 7: Pest Treatments Used



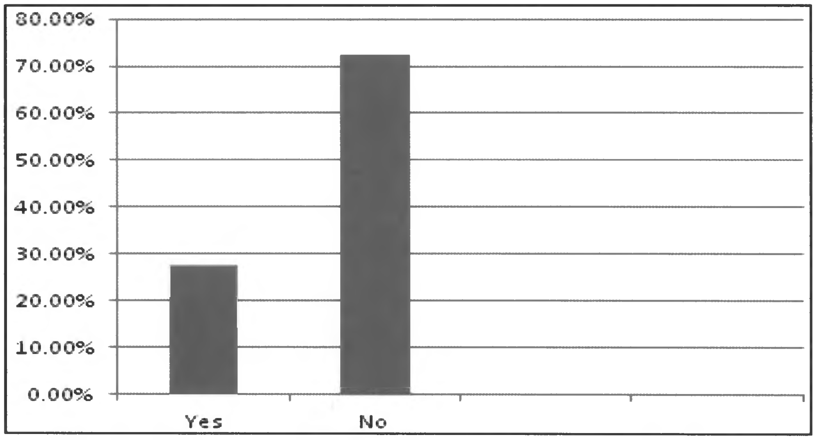
Question 6 asked about waste disposal: 6a asked how the waste is disposed of; as one might expect, 100% of responses noted proper disposal of waste. Question 6b asked about the rate of waste disposal, giving options of a daily or a weekly basis. Eleven respondents removed waste daily (61.1%), and seven removed waste weekly (38.9%) (Table 8)

Table 8: Waste Removal



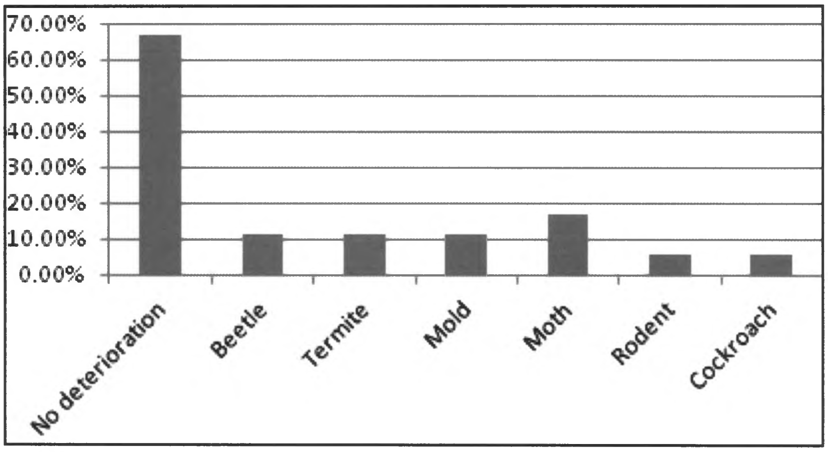
Question 7 asked whether or not the museum has a cafeteria in the vicinity of exhibit spaces (and if food is allowed near collection spaces at all). Five museums (27.8%) did have cafes, and 13 (72.2%) did not, but even those who have cafes specified that they were nowhere near the exhibit space. (Table 9)

Table 9: Presence or Absence of Cafes



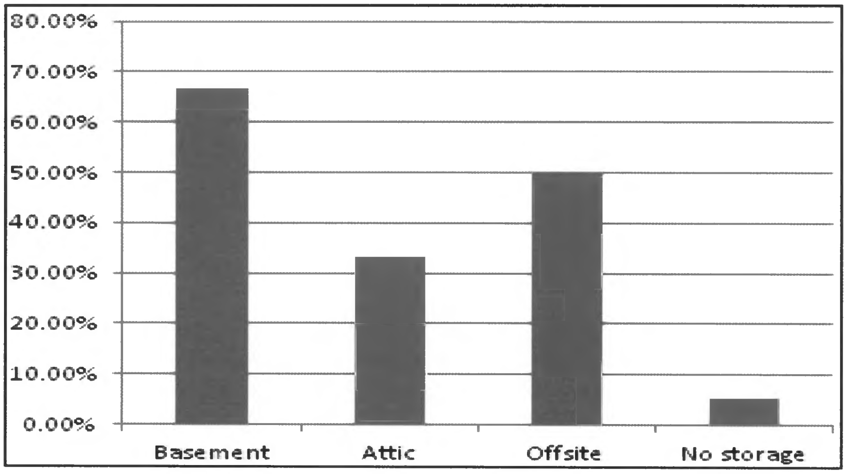
Question 8 asked about deterioration of exhibits caused by pest infestations, and how recurrence has been prevented. This question gave an open space for answers, rather than multiple choice answers, but it is capable of quantification: 12 museums noted that they have had no exhibit deterioration (66.6%) at all, 2 had termites (11.1%), 2 had mold, 2 had beetles, 3 had moths (16.6%), 1 had rodents (5.5%), and 1 had cockroaches (5.5%). Several museums (four to be more accurate) had more than one type of infestation (Table 10).

Table 10: Pest Deterioration



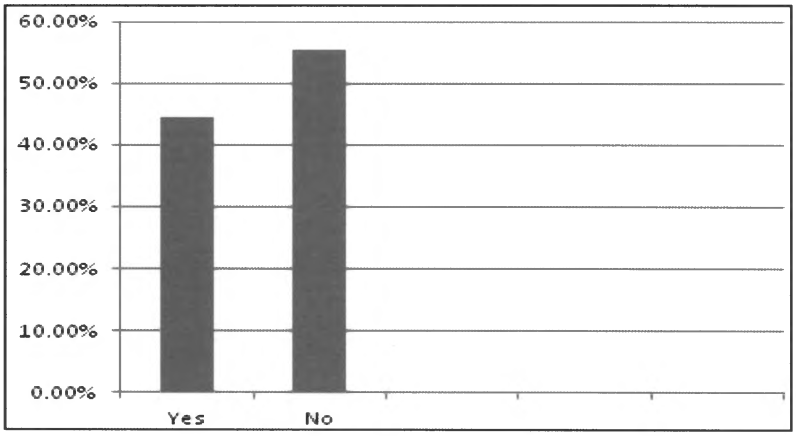
Question 9a asked where exhibits were stored when not in use: options given were basement, attic, off-site, all collections on display, or other. Of the 18 responses received, 12 museums stated that exhibits were stored in the basement, 6 were in the attic, 9 used off site locations, and one had all locations on display. As usual, most museums used more than one storage location (Table 11).

Table 11: Location of Exhibit Storage



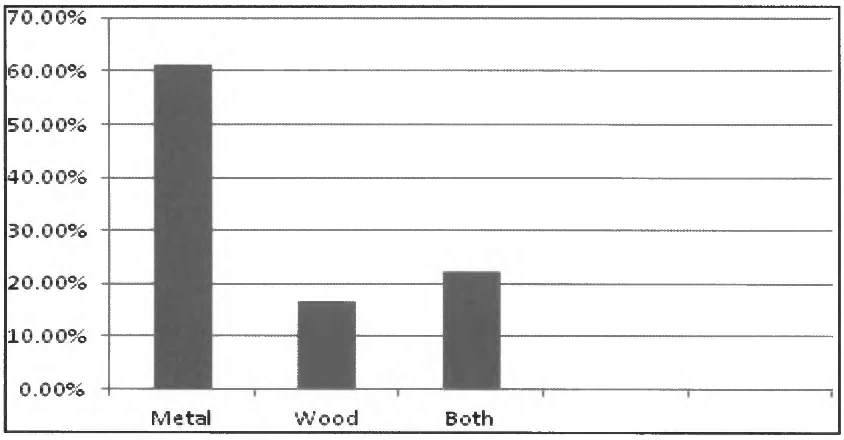
Question 9b asked if collection rooms were sealed, with options for Yes or No answers. Of these, 8 were sealed (44.4%), and 10 were not sealed (56.6%) (Table 12).

Table 12: Presence or Absence of Sealed Collection Rooms



Question 9c asked if metal or wood storage furniture was used. The overwhelming majority were metal: Eleven used solely (61.1%) metal, three used solely wood (16.6%), and four used both (22.2%) (Table 13).

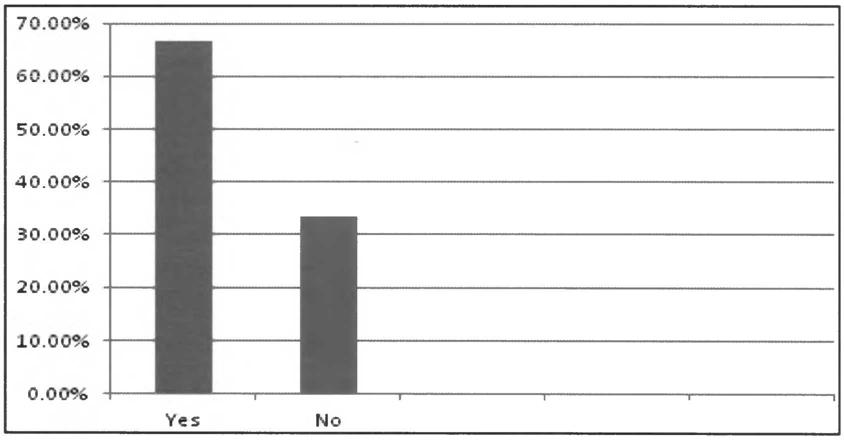
Table 13 Types of Storage Furniture Used



Question 9d asked whether or not HVAC systems lead into the storage area.

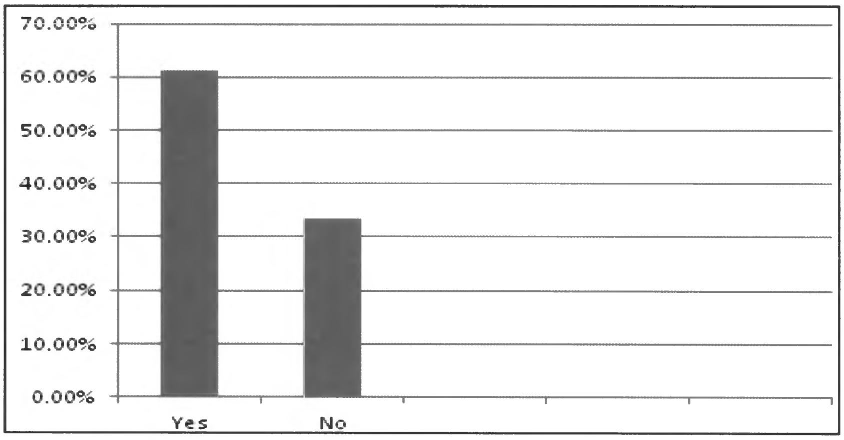
Twelve museums had HVAC in storage areas (66.6%) and six did not (33.3%) (Table 14)

Table 14: Presence or Absence of HVAC



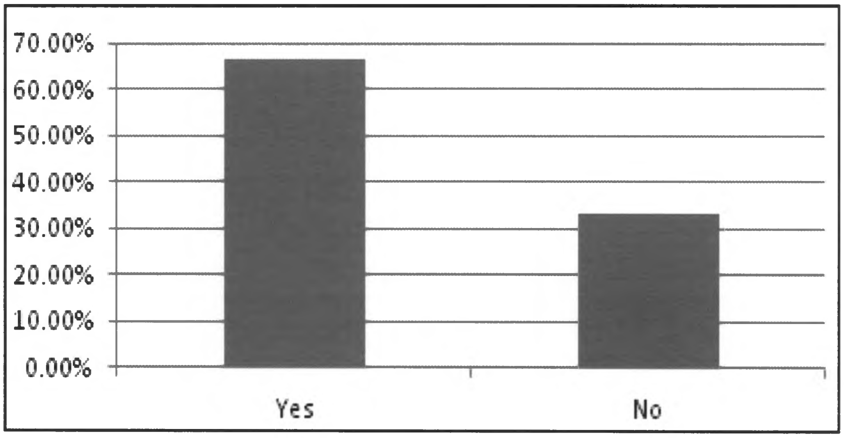
Similarly, 9e asked if collection areas had windows: Eleven had windows (61.1%), and seven (38.9%) did not (Table 15).

Table 15: Presence or Absence of Windows in Storage Areas



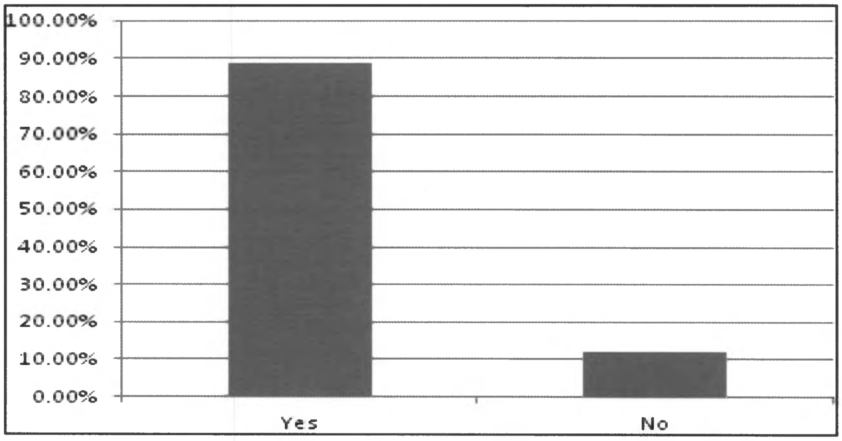
Question 10 asked if a formal housekeeping plan is used by the museum: Twelve did have a formal plan (66.6%), and six did not (33.3%)

Table 16: Presence or Absence of Formal Housekeeping



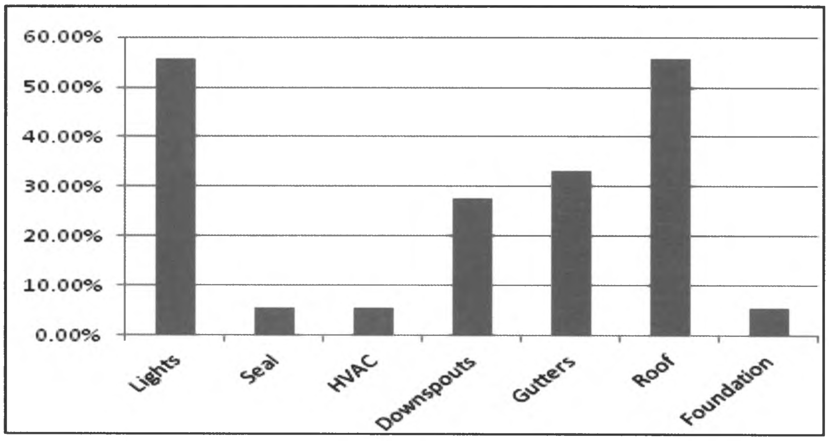
Questions 11 and 11b asked whether or not the building exterior was inspected for pests; 16 (88.8%) conducted regular inspections (meaning, at the very least, yearly), and 2 did not (12.2%) (Table 17). Question 11b was open ended and asked how often the inspection was done: most stated yearly (ten to be more specific), while a few responded monthly or daily.

Table 17: Presence or Absence of Regular Inspection



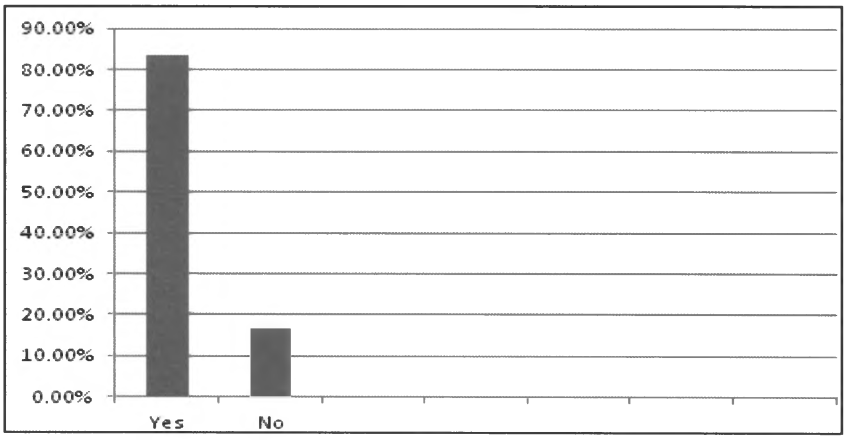
Questions 11c and 11d asked which parts of the building were inspected, giving options of lights, downspouts, seals, HVAC system, gutters, and roof. Of these, 10 inspected lights, 1 inspected seals, one inspected HVAC, 5 inspected downspouts, 6 inspected gutters, and 10 inspected the roof. Most museums inspected more than just one of these choices. One museum stated the foundation was inspected.

Table 18: Parts of Buildings Inspected



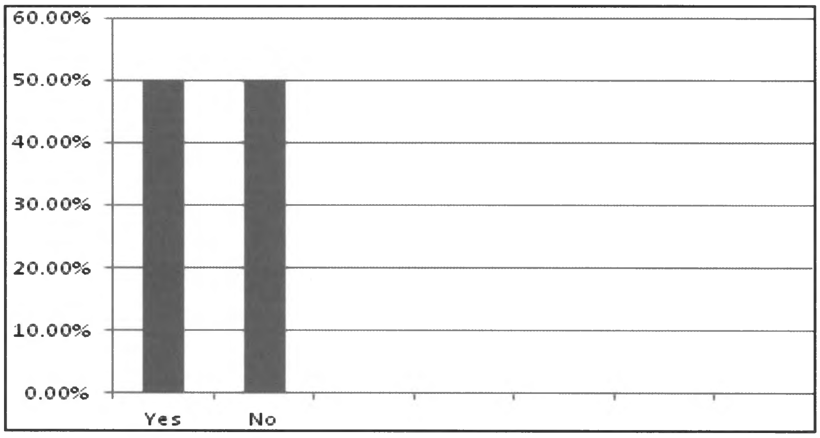
Question 11e asked if traps were placed around the interior to identify pests, and giving the option of Yes or No. Of the survey respondents, fifteen stated yes (83.3%), and three (16.6%) stated no (Table 19).

Table 19: Presence or Absence of Traps



Question 12 asked about the exhibit space of the museum, in square footage. This was an open ended question, and of course no two museums had identical square footages. Responses ranged from 2500 square feet to 500,000 square feet, with the average being about 100,000 square feet, and the median being 75,000 square feet. Question 12b asked if the exhibit cases were sealed to the bases; 9 were (50%), and 9 were not (50%) (Table 20).

Table 20: Sealing Exhibit Cases



Question 12c asked if air ventilation led into the exhibit areas: 14 stated yes (77.7%), 4 stated no (22.3%) (Table 21). The question also asked if the HVAC was inspected regularly: 10 (55.5%) said yes, 4 said no (22.2%), and the remaining 4 did not possess HVAC (Table 22). The final part of the question asked whether or not the HVAC was sealed. Six said yes (33.3%), 8 said no (44.4%), correlating to the 14 that had HVAC in the first part of the question (Table 23).

Table 21: Presence or Absence of HVAC in exhibit areas

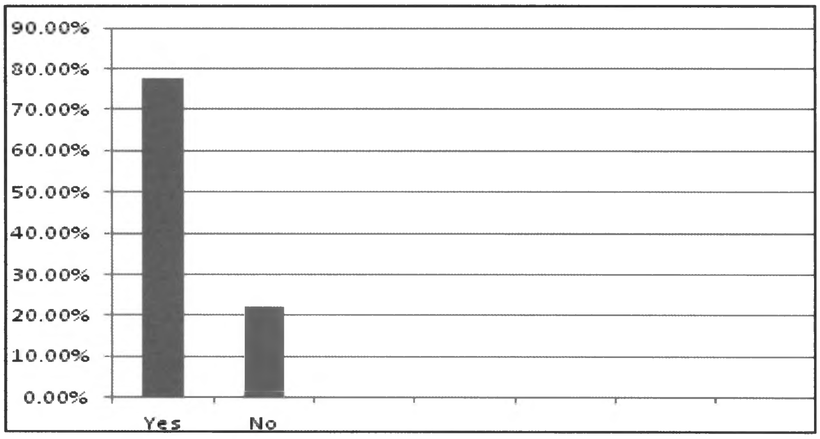


Table 22: Frequency of HVAC inspection

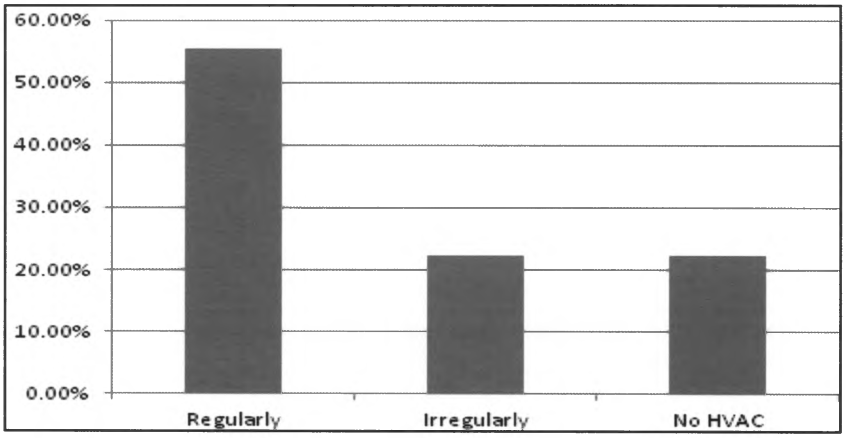
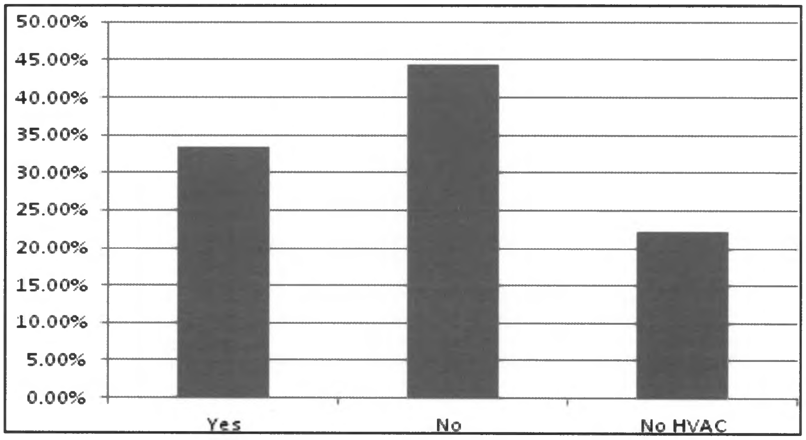
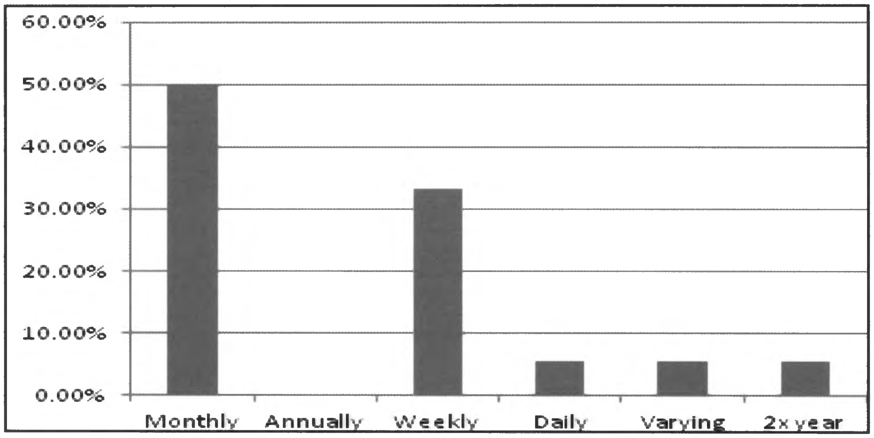


Table 23: Sealing or Non-sealing of HVAC



Question 12f asked how frequently the exhibit areas are cleaned: monthly, annually, or other (please describe). Nine responded that they clean monthly (50%), none clean annually (0%), 6 clean weekly (33.3%), 1 cleans daily (5.5%), 1 cleans different areas at different times, and one cleans twice annually (Table 24).

Table 24: Frequency of Cleaning



Question 13 inquired whether the museum contracted with commercial pest control services: 7 did contract with commercial pest control services, and 11 did not (38.8% and 61.2%, respectively) (Table 25). Of those that did contract (Question 13b), there was one contract for termites (5.5%), 5 for ants (27.7%), 4 for rodents (22.2%), two for hornets (11%), 2 for birds, 1 for beetles, 1 for moths, and 3 for general consultation (16.6%) (Table 26). As before, many contract for more than just one type of pest.

Table 25: Presence or Absence of Contracts with Commercial Pest Control Services

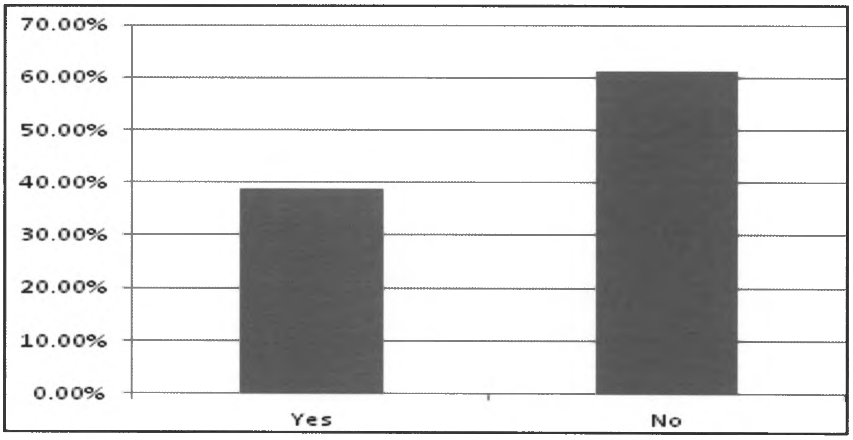
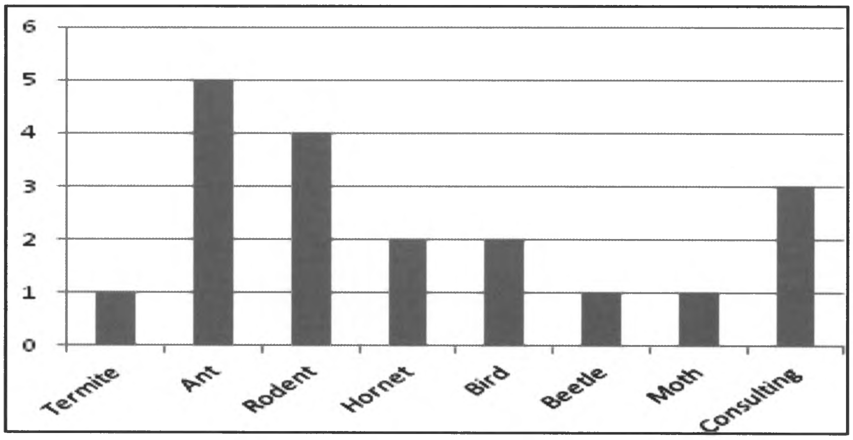
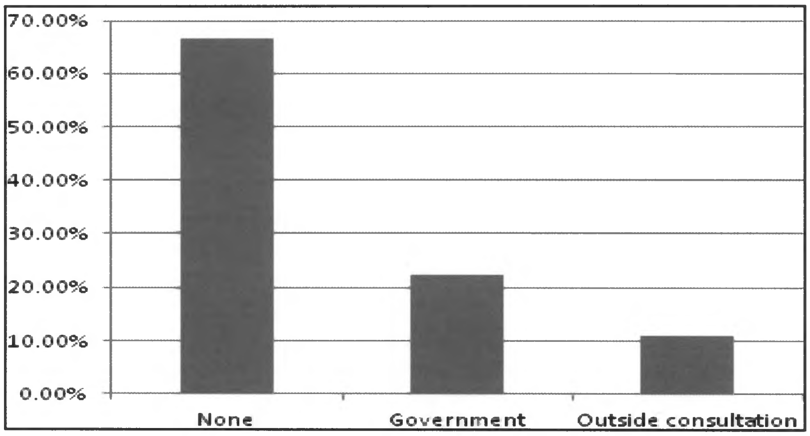


Table 26: Pests for which contracts are made



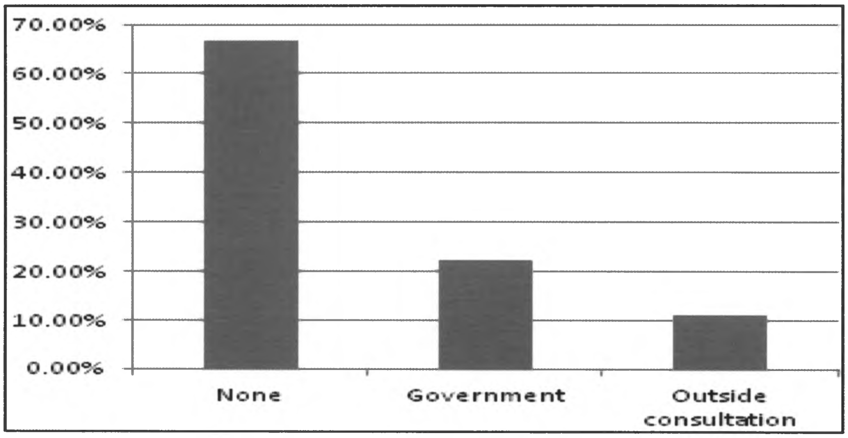
Question 14 asked which resources were used to formulate the IPM plan; this was an open ended question, and thus each museum has its own unique answer: 12 said none (66.6%), four stated that they based their guidelines off the federal government's IPM plan (22.2%), and two said outside consultation (11.1%) (Table 27).

Table 27: Resources for IPM planning



Question 15 was related to question 14, and asked about the review process of IPM plans. Twelve museums stated they had no review process (66.6%), 4 said the government reviewed the plan (22.2%), and two said outside consultation (11.1%) (Table 28). Thus, Table 28 below correlates to Table 27 above.

Table 28: Resources for IPM review



In the next chapter, the results of the survey will be discussed on a broader level, before presenting conclusions and recommendations in a final chapter.

Chapter 5: Discussion and Graphs

In this chapter, survey results will be analyzed and discussed in light of the literature review.

As outlined in the last chapter, 18 surveys were deemed valid from the total 95 surveys sent, resulting in a relatively low response rate of approximately 20 percent. The low rate of response may be due to the broad geographic reach of the survey or the selection process of the museums surveyed.

While a higher response to the survey would have been helpful for making broader generalizations, nevertheless, the responses supply important insight into practices in the field and the challenges that museums housing historical collections face in the area of Integrated Pest Management.

Below, a series of observations concerning the survey and the literature review will be outlined and briefly discussed.

First, half of all the museums that responded were from the Northwest, while a fifth were from the Northeast. The geographical proximity of the Museum Studies Program to museums in the Western region of the United States likely accounts for the higher response rate from museums in the Northwest. At the same time, almost half of the museums that responded held large collections. As a result, the survey supplies the most insight into IPM practices in museums in the Northwest with large historical collections. It may be that large museums, with more staff, are able to devote more time to the specialized activity of IPM, though as the literature review highlighted, all museums can develop and implement IPM.

Second, the most common issues IPM issues museums countered were budget issues, in almost two-thirds of the responses; climate control issues in more than half of museums; and recurring infestations in a little under half of all responses. Bearing in mind that many of the museums also stated that they had more than one IPM issue in their museum, the most significant issue encountered involved budget, followed by climate control issues, which can potentially have deleterious effects in terms of pest infestation. It appears that museums with budget challenges also faced pest infestations, and that some museums facing infestation issues also encountered climate control issues. Overall, an association appears to exist here between insufficient budget and infestations, i.e., IPM materials, such as the traps and baits mentioned in the literature review, cost money.

Third, a significant finding is that almost three-fourths of the museums surveyed utilized a formal IPM plan. In addition, of the museums with no reported infestations, nearly all had formal IPM plans in place, confirming the utility of IPM, as outlined in the literature review.

Fourth, a roughly even division was found between museums with designated quarantine areas and those without. However, even in museums without designated quarantine areas, the act of segregating infested objects from non-infesting objects was common.

Fifth, the most common treatments used for pests were freezing and green pesticides. It is worth noting that several museums used more than one method, and many other museums responded that they used none of the listed treatments, but vigorously monitored and inspected areas instead, and that these efforts were sufficient in keeping pests away. At the same time, it appears that none of the preventative measures were used by a majority of museums, with the plurality using green pesticides. No museum stated the methods they used were ineffective, so it can be theorized that any of these techniques can be effective if used properly.

Sixth, as one might expect, 100% of respondents noted the proper disposal of waste. Almost all museums removed waste either daily or weekly. Clearly, no museum wants to keep its waste for multiple weeks at a time, and thus seek to remove it quickly. The survey responses do not elaborate why the museums chose one rate of disposal or another, nor do they suggest the amount of time less than a week that would be ideal in IPM plans.

Seventh, almost three quarters of museums did not possess cafes. Of those that did possess cafes, most also responded that cafes were located nowhere near exhibit spaces. Thus, there is an overwhelming consensus to keep food and drink away from collections objects.

Eighth, two thirds of museums had not experienced deterioration of exhibits caused by pest infestations. Of the museums that had experienced deterioration of exhibits caused by pest infestation, a diversity of insects were reported as responsible, perhaps reflecting the range of objects that comprise historical collections. Several museums had more than one type of infestation. The preventative methods outlined earlier, including the presence of formal IPM plans, seem to be effective due to the relatively low amounts of pest infestations.

Ninth, when not in use, most museums stored exhibits either in basements or in off site locations. As expected, most museums used more than one storage location. While it might be assumed that storage in basements or in off site locations are more conducive to infestations, it appears that a more critical variable is the presence of a formal IPM plan, no matter what the specific location.

Tenth, museums not possessing sealed collection rooms were a narrow majority over those that did have sealed rooms. Since none of the museums had a particularly large amount of infestations, it can be surmised that sealing collection rooms is helpful, but not essential. In addition, almost two thirds of museums used metal furniture, while just under a fifth continued to use wood, despite the fact that wood is susceptible to pest infestation. At the same time, two thirds of museums had HVAC in storage areas. Clearly, as the literature review indicated, HVAC is beneficial, particularly for certain types of collections that need climate control, such as paintings, but with an effective IPM plan in place, it may not be essential, especially for museums facing budget issues. Finally, almost two thirds of museums possessed windows, confirming that historical collections are housed in less than ideal settings but that the presence of window need not indicate that pests cannot be controlled.

Eleventh, two thirds of museums had formal housekeeping plans in place. In this context, "formal housekeeping plan" typically referred to an on-site custodial staff that works scheduled shifts. Significantly, all of the museums in this survey specified that housekeeping is important to their pest control efforts, whether they formally or informally clean. Moreover, three other related points can be made: 1) almost all museums inspected the building exterior regularly for pests; 2) the most inspected part of buildings were roofs and lights (undoubtedly since insects often access collections areas via roof and are also attracted to light), while some of the building areas listed were, somewhat surprisingly, barely inspected at all, such as seals; and 3) almost all museums placed traps around the interior to identify pests. Along with housekeeping, these points all demonstrate the importance of vigilance in preventing pests from accessing or establishing a foothold in collections, as highlighted in the literature review.

Twelfth, as expected, no two museums had identical square footage for their exhibit spaces, but the median response was about 75,000 square feet, on the high side, suggesting that most respondents were museums with larger exhibition areas. In addition, half of respondents sealed exhibit cases to the bases, while half did not. Sealing exhibit cases can thus be considered similar to the sealing of collection areas: helpful, but not essential.

Thirteenth, more than three-fourths of museums possessed HVAC in exhibit areas, and most stated that it was inspected regularly, suggesting that museums with historical collections consider well-functioning HVAC essential for both the structural integrity of exhibits and the comfort of museum visitors, as the literature review indicated. It is seems apparent that HVAC in collections areas, though expensive, would supply similar benefits and that it would support preventative care in collections areas as well. At the same time, respondents indicated that almost all clean exhibit areas every 30 days or less, confirming that regular cleaning is of the utmost importance, as no museum cleans any less than annually.

Fourteenth, most museums did not contract with commercial pest control services. The results here indicate that contracting for pest control may be of assistance, but one can make an IPM plan using resources and working independently. Of those that did contract, rodents were the most common pest.

Next, two-thirds of museums stated that they did not use external resources to formulate their IPM plans, while just over one-fifth based their guidelines on federal government IPM plan. Given all the resources outlined in the literature review, this is surprising, and it suggests those working on IPM plans should access professional resources more often. However, since the IPM plans developed appear to be effective, it also suggests that the training of those responsible for developing the plans is sufficient. Finally, more than two thirds of museums stated they had no review process for their IPM plans. Once again, since the IPM plans developed appear to be effective, this suggests that the training of those responsible for developing the plans is sufficient.

In the next chapter, conclusions and recommendations about IPM in museums that house historical collections will be presented.

Chapter 6: Conclusions and Recommendations

In this chapter, several conclusions concerning the state of IPM in museums historical collections will be presented. First, a summary of the results of the survey will be outlined, followed by main conclusions, and finally, the analysis will conclude with a set of recommendations to the museum profession concerning IPM in museums housing historical collections.

Summary of Survey Results

The national survey of IPM practices in museums caring for historical collections revealed that the overwhelming majority of the museums have either partial or complete IPM plans. Significantly, every single museum profiled also considered cleaning and maintenance to be a major part of their pest control. Beyond this, the majority of the museums also committed to regular inspections; many used quarantines, anoxic chambers, freezing or heating chambers to address infestations; and a small majority used traps and green pesticides. Although the survey results were more representative of larger museums, these trends existed across museums of all sizes, indicating the practicality and universality of these methods in museums caring for historical collections.

Overall, the survey indicated that the most important issues museums face in terms of pest management are a perceived lack of budget, followed by climate control issues. Surprisingly, budget and climate control issues were not found to have a major impact on pest management. For example, several museums noted that they did not have HVAC in the collections area, and also stated that they did not have any pest infestations.

Similarly, those with a lack of budget indicated that they were vigilant in housekeeping and observation, and that this was sufficient for pest control. This suggests that museums caring for historical collections have been nimble in adapting to the challenges they face, and that staff recognition of baseline activities, such as housekeeping, can have a major impact in managing pests.

Conclusions

Based on the survey results and the review of literature on Integrated Pest Management conducted in this thesis, four main conclusions can be outlined: first, museums with historical collections have largely integrated IPM into their efforts; second, housekeeping and preventative care are the two key parts of IPM, either in formal or informal plans; third, IPM can present budget issues but it can be conducted with minimal costs; and finally, museums caring for historical collections need to move beyond housekeeping and vigilance and develop formalized IPM plans that draw on practices outside the history sector.

The Integration of IPM into Museums with Historical Collections

Historical collections are present in a broad range of museums, whether or not the museum has "history" in its title. At the same time, historical museums have many specialized collections that they must care for, ranging from objects associated with a uniquely singular theme which lends its significance to a particular industry such as a museum of puppetry, railways or textiles, to those that reference the localized region and its history and culture. As a consequence, the range of historical collections that exist in the museum world is both astonishing and sobering, since these collections are not only irreplaceable, but attractive to pests.

As outlined previously in this thesis, IPM began to be adapted by museums in the 1990s, especially by large museums such as the American Museum of Natural History and the Smithsonian. These museums have the types of collections that are especially susceptible to pest infestation, such as skins and textiles. In the years since, smaller, less well-funded museums have begun to adapt integrated pest management as well.

The survey results presented here indicate that museums with historical collections have largely integrated IPM into their efforts. This is significant because these museums have come to the recognition that the most cost-effective procedure to implement in their collection is IPM. Their collections as constituted consist of a wide range of items, including, most notably from the perspective of pest management, organic materials such as wood, textiles, animal products such as leather, and associated archival documentation. As outlined many times above, organic items, including documentation housed in cellulose-based archives, can be quickly ravaged by many common forms of infestation.

The advent of Museum Studies programs at the graduate school level can provide smaller history museums with trained professionals while offering coursework and internships in IPM. Many trained professionals are sensitive to the nature of the historical collections, and even those without direct experience of historical collections are aware of IPM techniques, and can adapt them as needed.

Housekeeping and Preventative Care

While the literature review indicated that IPM includes a standard array of pest management techniques, the survey suggested that the most striking commonality among museums with historical collections was the pervasive practice of housekeeping and vigilance. It is therefore clear that housekeeping and preventative care are the two key parts of IPM plans, either in formal or informal plans.

Housekeeping is important as it deprives all pests of access points to at-risk collections, and removes sources of food for certain types of pests that prey upon organic waste and other materials that are not necessarily exhibits (such as flies and cockroaches). The key components of a proper housekeeping plan are knowledge of typical pests in a museum (availing oneself of entomology literature and IPM literature, as well as observing the typical pests in the end user's particular museum), combined with cleaning these areas, vigilance, and utilization of traps (sticky traps, pheromone baits, etc.).

IPM Budget

While certain IPM techniques can be expensive, such as freezing chambers, as well as certain types of organic pest control and pheromone baits, the utility of housekeeping and observation, and its prevalence in IPM, makes it one of the cheapest methods of pest control possible. The survey results reported that for many museums, no infestations had occurred since the programs were implemented, while infestations had occurred in the years prior to the implementation of IPM. Therefore, the "sweat equity" of the staff in the form of building related practices and procedures and a chain of command of duties and responsibilities has been proven effective in combating infestation.

The survey results also indicate that budget issues involving IPM are indeed an issue for some museums that hold historical collections. Interestingly, however, the general costs involved in developing and implementing IPM plans was not a major topic of concern in the literature, and IPM challenges specific to historical collections also do not appear to be well documented to date in the body of literature. As a result, collection managers caring for historical collections might therefore be advised to not only keep a record of infestation as part of their IPM efforts, but to carefully track staff time and the budgetary costs of implementing such programs.

Formalized Plans

Significantly, none of the museums surveyed indicated that they returned to using traditional methods of pest control once they had switched to IPM, nor did any of the museums surveyed indicate that their IPM techniques were not working, and thus, they stopped using them. Thus, while IPM has made firm inroads into history museums, museums caring for historical collections need to move beyond housekeeping and vigilance and develop formalized IPM plans that draw on practices outside the history sector.

The reason why a range of museums, including those with historical collections, have increasingly turned to IPM is likely due to the efforts of museum professional groups such as the Society for the Preservation of Natural History Collections and the

American Alliance of Museums; increased professionalization of museum staff; the growth of Museum Studies training programs; the inclusion of the topic as a key subject in core collections management resources; and the availability of IPM policies from larger museums such as the Smithsonian or the American Museum of Natural Museum. Today, museums with historical collections, which are often small, volunteer-run, and under-resourced, can choose selectively from a "shopping list" resources to fit budgetary constraints.

Recommendations

Below, three recommendations are enumerated for the museum profession concerning IPM in museums housing historical collections.

First, museums with historical collections should avail themselves of the literature developed for natural history museums to deepen their plans. Although IPM is a relatively new method of pest control, only originating in the last few decades, the amount of literature on the topic, especially in the natural history museum sector, is considerable. Several museums involved in this thesis cited specific works of IPM literature, such as the already existing IPM plans of other institutions, federal pest management guidelines, or entomology textbooks that are also cited in the body of this thesis.

Second, IPM plans should continue to be developed by museums that care for historical collections, particularly with an emphasis on housekeeping for all museums—IPM is low cost and can pave the way for development of formalized IPM plans over time. As repeatedly mentioned in this thesis, housekeeping was specifically cited as a major part of the IPM plans of every museum surveyed, including by museums that had not yet adopted a comprehensive approach to IPM.

Third, the number of museum professionals trained in IPM as well as in best practices in collections management in the context of historical museums will increase in the future, and their professional expertise should be utilized. While many smaller history museums have professionalized over the past 20 years, these institutions should continue to expand their employee base and their employee's skill sets. With over 17,000 museums in the United States, the uniqueness of many of these institutions in both their subject matters and associated collections will require well-trained professionals to integrate the presentation of history and culture with best practices and standards in collections stewardship, of which IPM is a prime example.

Closing Comments

From multiple perspectives, the IPM system is a significant advance in collections stewardship over traditional methods. While museum staff that care for historical collections recognize this, more efforts must be taken to educate the leaders that run these kinds of museums that IPM is a cost-saving measure that, with due diligence, can reduce both budgetary considerations and any infestations that may be triggered.

IPM is a burgeoning field that requires knowledge in a range of important areas, such as best practices in collections stewardship, entomology, the physical nature of collections, and museum and historic site architecture. IPM has grown greatly in the last two decades, and will continue to develop as more institutions become aware of its numerous benefits in preserving the unique and irreplaceable collections housed by North American historical museums.

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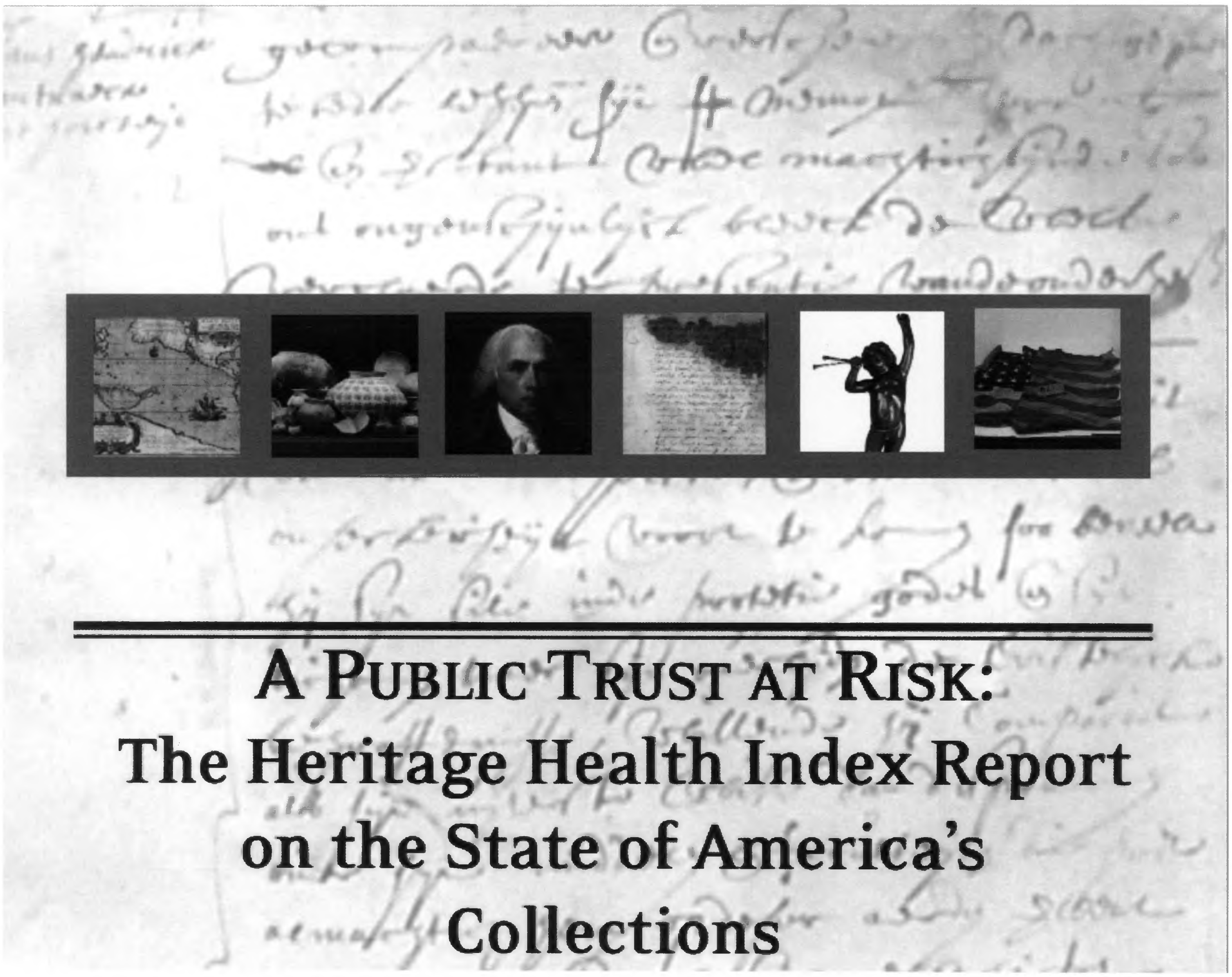
Appendix 1

Heritage Health Index Report Excerpts



more than 80% of their collections stored in adequate areas.

Considered by size, large institutions and medium-sized institutions are more likely to have more than 80% of their collections stored in adequate areas, but the figures for large and mid-sized institutions are relatively similar (large 46%, medium 42%, and small 33%) (figure 6.3). Viewed by governance, the results are relatively similar, with the exception of 25% of tribal-governed institutions having no collections stored in adequate areas. More than 80% of collections are stored properly at 42% of federal, state, and county/municipal institutions. The percentage of collections in adequate storage does not differ significantly by region.

Survey respondents were asked to indicate where improvements were needed for storage that is not adequate. They were given four categories of improvement: additional on-site storage, additional off-site storage, renovated storage space (either on-site or off-site), and new or improved storage furniture/accessories (such as shelves, cabinets, racks). Figure 6.4 illustrates the need and urgent need for storage improvements. About two-thirds of institutions indicated need in each of the four categories. There is an urgent need for additional on-site storage at 32% of institutions, storage renovations at 31% of institutions, new/improved storage furniture at 29% of institutions, and off-site storage at 23% of institutions. Among institutions that selected urgent need in more than one category, 3% selected urgent need for all four, 7% for three, and 11% for two areas of improvement to storage. Results are fairly equal across institution types, but one-third of archives, historical societies, and museums have an urgent need for new/renovated storage, compared with one-quarter of libraries and archaeological repositories/scientific research collections having an urgent need for storage renovations. By size, results are close to the totals, with the exception of large institutions having a greater urgent need for off-site storage (32%).

Fig. 6.4 Institutions' Need for Storage Improvements

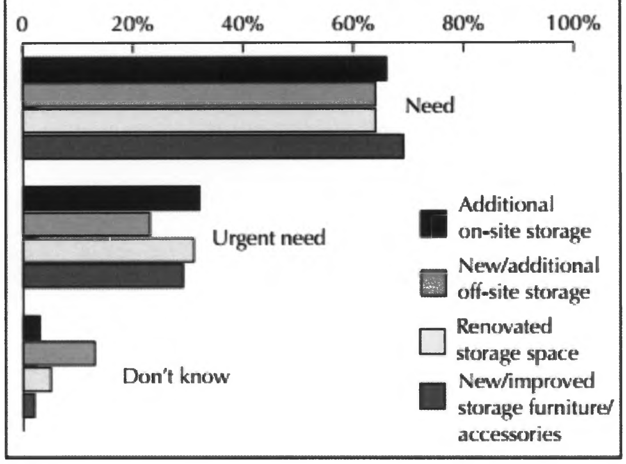
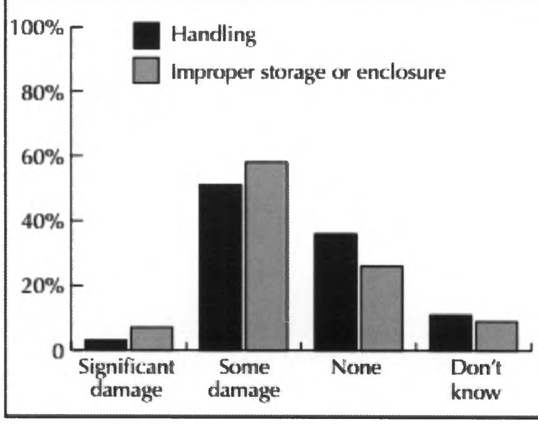


Fig. 6.5 Institutions Reporting Causes of Damage to Collections from Storage Conditions



Improper storage or enclosures, which could cause collections to be crushed, bent, creased, adhered together, broken, or otherwise damaged, ranks as one of the greatest threats to collections documented by the Heritage Health Index. As seen in figure 6.5, 7% of institutions have had significant damage to collections due to improper storage or enclosures, and 58% have had some damage. Damage from handling can also be related to improper storage because cramped conditions make item retrieval by staff or researchers risky. Significant damage due to handling has occurred at 3% of institutions, and some damage from handling has happened at 51% of institutions.

Fig. 4.43 Condition of Historic and Ethnographic Objects (by specific type)

	Quantity	In unknown condition	In no need	In need	In urgent need
Textiles	9.5 million	26%	39%	30%	5%
Ceramics and glass artifacts	10.8 million	21%	55%	22%	2%
Ethnographic and organic collections	6.8 million	23%	40%	27%	9%
Metalwork	3.2 million	35%	45%	17%	4%
Furniture	1.6 million	27%	41%	26%	6%
Domestic artifacts	7.1 million	29%	44%	21%	6%
Science, technology, agricultural, medical artifacts	4.7 million	28%	45%	23%	5%
Other historic and ethnographic objects	3.3 million	44%	35%	16%	5%

APPENDIX 2

Search Portal for AAM Accredited Museums

Home > Assessment Programs > Accreditation > Accredited Museums

Museums Committed to Excellence

The following institutions are part of the Continuum of Excellence. They have committed to operating according to national standards and best practices in a variety of ways.

Use this search tool to find museums that have:

- Taken the Pledge of Excellence
- Participated in MAP (since 2002)
- Completed Core Documents Verification
- Achieved Accreditation

Search by museum name or designation. All museums on this list have taken the Pledge of Excellence.

Want to add your museum to this list? Learn how.

Accredited Museum Core Documents Verified Museum MAP Museum

Search

Search by state Accredited Museums Core Documents Verified MAP

2573 institutions have taken the Pledge of Excellence

Alberta

Appendix 3

American Museum of Natural History Pest Management Policy

Integrated Pest Management

General Information on IPM and Collections

Preventing specimens from being attacked and damaged by pests is a major challenge of collection management. In collections facilities, the two most common types of pests are insects and fungi.

In the past, pest management usually involved regular applications of toxic chemicals (pesticides or fungicides) to specimens and collection areas. In recent years, however, health and safety concerns have led institutions to move away from this approach in favor of preventative and protective measures that are not based on chemicals. These include upgrades and repairs to building structure; installing better cabinetry; better control of temperature and humidity in collections areas; removing food and other organic materials from collection areas; more effective monitoring; and treatment of outbreaks through freezing or anoxic environments. Using these different measures in combination is known as "integrated pest management."

Objectives for an institutional IPM plan

- To develop collection management practices that are consistent with city, state, and Federal health safety regulations
- To foster good communication with other departments responsible for ensuring the success of an IPM Plan (e.g. Facilities Operations and Custodial Services)
- To facilitate a swift and unified response to pest problems among departments with the understanding that the achievable goal is management; no policy will ever eradicate the pest problem

The first step in an IPM plan is preventing access – determining how pests enter your building and modifying behaviors and habits that enable pests, once in, to continue to live and breed. Preventing access will include the following:

- Identifying and fixing problems in the building and room structure that allow pests entry (e.g., cracks in roofs and walls, doors and window seals) and then, ideally, providing for well sealed cabinets that deter access to specimens.
- Maintaining an environment in collections areas that is not hospitable for pests. Pest infestations can sometimes be directly related to **temperature and relative humidity**. Ensure that collections areas do not have high heat or humidity conditions that will allow pest populations to flourish.
- Keeping food and food preparation far away from collections housing.
- Making sure that collection areas are kept clean and free of trash, debris and foodstuffs that could encourage pests. Good housekeeping helps prevent infestations.
- Developing new collection procedures to make sure that new collections and packing material are safe to enter collections areas.

Use of Solid Wood Packing Material (SWPM)

- A particular issue affecting the transport of paleontological specimens from the field is the use of solid wood packing materials; because of their weight, paleontological specimens frequently are shipped in wooden crates and pieces of wood are often used to provide additional strengthening for large field jackets. SWPM refers to primary wood packing materials such as crating, pallets, packing blocks, drums, cases and skids.
- SWPM is vulnerable to attack by wood boring insects; crates and pallets made from untreated wood are thought to have been the source of the **1996 outbreak of the invasive Asiatic long-horned beetle (*Anoplophora glabripennis*)**. In a collection environment they may cause serious damage to untreated wood artifacts, furniture, and structural timbers. Failure to use appropriately treated SWPM, and to provide evidence of such when shipping specimens into the country, may be grounds for denial of entry, destruction of the shipment, and legal sanctions including fines.

Solid Wood Packing Material (SWPM)
SWPM refers to primary wood packing materials such as crates, pallets, packing blocks, drums, cases and skids. SWPM is vulnerable to attack by wood boring insects which, in a collection environment, may cause serious damage to structures, office furniture, artifacts and specimens. For institutions that transport exhibits or large specimens internationally it is essential to be aware of the legal requirements for documentation and treatment of SWPM.

The second part of an IPM plan is **monitoring**. All buildings have their own ecosystem based on their location and other historic factors. Some pests will always be found inside. Monitoring this ecosystem provides a useful way to determine what species are common in your facility and when conditions might have changed to allow one species to become common enough to present a danger to the collections. Insect traps, such as sticky traps or pheromone traps, are commonly placed throughout collection areas and checked on a regular basis, recording the contents. Pest sightings or an uptick in pest activity should prompt an investigation into potential causes.
If pests are found in traps **identification** is an important third step. Identification will allow decisions to be made on how potentially damaging the activity may be to the

collection. Identifying the pest also aids in ensuring that a proper course of remedial action is chosen.

Elimination is the fourth element of an IPM plan. The use of chemical agents to deal with either routine pest mitigation or more entrenched infestations should be left to professional pest management companies who are trained and licensed in accordance with state regulations and health and safety standards. To deal with infestations at the specimen or collection level the two most common procedures are low-temperature (freezing) or low oxygen (anoxia) treatments.

For More Information on IPM visit **www.museumpests.net**. This website is a product of the Integrated Pest Management Working Group (IPM-WG) – an ad hoc group of museum professionals (collection managers, entomologists, conservators, etc) – which has put together useful tools for collecting institutions to help them implement and run integrated pest management programs. The IPM-WG is sponsored by the American Museum of Natural History.

Collection Specific

IPM and Invertebrate Zoology Collections

Entomology collections are, ironically, extremely vulnerable to pest infestation. Many large collections have been treated in the past with heavy metal pesticides and, in more modern times, with fumigants to ward off invaders but these do not fully protect collections from infestation. Researchers must be aware of the history of pesticide and fumigant use for their own safety (see the section on Residual Pesticides in the Health & Safety section of this site for more information). Tips for keeping invertebrate collections safe from pests include:

- Use inert materials for specimen storage (e.g. polyethylene foam rather than cotton wool)
- Use well sealed cabinets for storage.
- Keep the RH low. If entomology collections must be stored in environments prone to damp (e.g. basements) they should be in microenvironments (i.e. storage cabinets) with a desiccant such as silica gel.
- Inspect collections quarterly looking for frass, insect excrement which often looks like sand or sawdust.
- If there is concern that a specimen is infested it should be frozen.

IPM and Vertebrate Zoology Collections

Hair and skin of vertebrate zoology collections make them extremely vulnerable to pest infestation. As a result most collections have been treated in the past with pesticides and/or fumigants. Researchers must be aware of the history of their collections for their own safety (see the section on Residual Pesticides in the Health & Safety section of this site for more information). Mammalogy collections do well in cold storage conditions that are inhospitable to pests. Osteological collections too are vulnerable to infestation as the fat/grease in the bone is extremely attractive to insects.

Mothballs and substances such as Vapona® are no longer legal or appropriate treatments for museum collections. If an infestation is suspected, skins, skeletons and full taxidermy mounts can generally be safely frozen which will kill all life stages of a pest infestation (for more on proper freezing procedures visit the Treatment page of the museumpests.net website). [http://www.museumpests.net/treatment.asp] Infestations that cannot be dealt with by freezing should be treated by an appropriate, licensed pest management professional.

IPM and Paleontology Collections
While most fossils are not prone to infestation, pests can affect certain categories of paleontological material (e.g. subfossil bones or mummified specimens) or sometimes the adhesives used on specimens. Pests can cause damage to associated items, such as specimen labels, paper archives, padding materials, or drawers and cabinets. Poor pest management may lead to the paleontology collections becoming a reservoir for pest problems elsewhere in an institution.

IPM and Physical Sciences Collections
As with paleontological specimens, physical science collections are not prone to infestations but should be monitored to ensure that they do not become a breeding ground for infestations that could spread to other more vulnerable areas of an institution. Pests can damage specimen labels, padding, drawers and cabinets that are essential for the proper care of geological collections.

Additional Resources
The website of the IPM-Working Group **www.museumpests.net** was specifically developed to present resources for implementing IPM and treating infestations in museums and other cultural institutions. Resources include the PestList, a listserv for questions relating to IPM, templates for developing IPM policies and procedures, identification and treatment fact sheets and bibliography and web resources.
The National Park Service Conserve-O-Gram series has several documents that deal with IPM including:

- 3/4 - Mold: Prevention of Growth in Museum Collections **[http://www.nps.gov/history/museum/publications/conserveogram/03-04.pdf]**
- 3/6 - An Insect Pest Control Procedure: The Freezing Process **[http://www.nps.gov/history/museum/publications/conserveogram/03-06.pdf]**
- 3/7 - Monitoring Insect Pets with Sticky Traps **[http://www.nps.gov/history/museum/publications/conserveogram/03-07.pdf]**
- 3/8 - Controlling Insect Pests: Alternatives to Pesticides **[http://www.nps.gov/history/museum/publications/conserveogram/03-08.pdf]**
- 3/9 - Anoxic Microenvironments: A Treatment for Pest Control **[http://www.nps.gov/history/museum/publications/conserveogram/03-09.pdf]**
- 3/11 - Identifying Museum Insect Pest Damage **[http://www.nps.gov/history/museum/publications/conserveogram/03-11.pdf]**

Combating Pests of Cultural Property by Tom Strang and Rika Kigawa of The Canadian Conservation Institute has comprehensive information on IPM.
Canadian Conservation Institute Notes offer practical advice about issues and questions related to the care, handling, and storage of cultural objects. Relevant Notes include:

- N3/1 Preventing Infestations: Control Strategies and Detection Methods

- N3/2 Detecting Infestations: Facility Inspection Procedure and Checklist
- N3/3 Controlling Insect Pests with Low Temperature
- N3/4 Psocids or "Book Lice": a Warning of Dampness

Appendix 4

Smithsonian Institute Pest Policy

An IPM Checklist for Planning & Implementing Pest Control on Art & Artifact Collections

I. Is Pest Control Necessary?

A pest is an unwanted organism - animal, plant, bacteria, fungus, virus, etc.

What pest problem do you have? bats, mice, birds, rats, mold (fungus), insects

What collections in your museum are affected? basketry, ceramics, frescoes, glass, metals, paper, paintings, stone, structure (building itself), textile (wool/camelid, cotton), wood (softwood, hardwood)

Some pest problems (like fleas) may bother the staff or collection's owner, but pose no threat to artworks or artifacts. Sometimes such insects as ladybugs or such animals as geckos are inconsequential, or even beneficial, to the home or museum environment.

Many types of collections are not attacked by pests, but their housings may be susceptible to infestation. Certain collections in certain climates are usually safe; certain collections in certain climates are at risk; come collections are attacked most often.

II. Will Pest Control Be Effective?

Is there a chemical or nonchemical treatment that you are currently using?

Does the pest problem persist?

Does the pest problem return? the next week, month, season, year

Where is the pest problem?

Where does the pest come from?

What does the pest like to eat?

What is the life cycle of the pest?

What does it need to survive? food needs, harborage needs, preferred light levels, preferred temperature levels, preferred humidity, preferred living arrangements (space)

For example, some cockroaches in the United States prefer a space 3/16 inch wide; they like cracks and crevices and the dark; they will eat anything organic; they like starchy food; and corrugated boxes are attractive to them.

Integrated pest management uses chemical and nonchemical methods to reduce and eliminate pest problems in the following steps:

1. Inspection

Building structure. Does the structure invite pests into the museum via the roof, eaves and ledges, doors, windows, air vents, wall crevices, drains (inside and outside), floors, attics, basements?

Cleaning. Do maintenance schedules or housekeeping policies - about food, food supplies, equipment, museum supplies, trash removal, desks and table space cleaning, flowers, indoor and outdoor plants, closets, closed spaces, floor cleaning - make the collection a better places for the pests to live?

2. Diagnosis and Reporting

Catch examples of your pest (kill but do not squish) using sticky (unbaited) traps; sticky (baited) traps; pheromone traps; or black light traps (not good for your eyes). Collect examples of pest damage and leavings. Identify the pest; go to an entomologist (also see References). Learn its preferred diet, life cycle, and habitat. Record the location and date the pests were found to determine what areas of the collection are infested.

Note: Some insects will not be attracted to baits or traps. The "carpet beetles" that attack wool in the United States and Europe like only the dead insects already in the old traps. Other insects will die on you desk or shelf and be easy to find, like the *Stegobium paniceum L* (drugstore/spice beetle) and the *Lasioderma Serricorne F* (the cigarette beetle). Cockroaches will hide and be caught in sticky traps if the traps are placed in dark corners or damp places and if cockroaches are present. *Do not carry out pest control on a pest that does not exist!*

3. Planning Pest Management Strategy

Match the pest control to the pest and match the treatment to the particular pest: to where it lives and what it eats, to the museum, to the people who work in the museum, and to the object.

Mechanical and physical control. Decide how to change your museum structure - vents, drains, screens, doors, plants, or windows. For example, to keep birds away, remove vines and bushes from exterior walls; to keep cockroaches away, remove leaves and grass clippings.

Cultural control. Decide how to change people's work (or eating) habits in the galleries, offices, library, and storage rooms. For example, do not leave food or wrappers in wastebaskets overnight; do not leave dirty dishes in the sink.

Sanitation. Decide how to make living in the museum more difficult for the pest. For example, make sure all windows have screens; to stop cockroaches from coming up around pipes, caulk all openings.

Biological control. Decide if another organism will solve a problem. For example, a cat in the garden might help catch mice.

Chemical control. Try local treatment, specific to the habits of the insect. For example, spray cracks and crevices for cockroaches; then set baited traps in dark corners.

4. Implementing the Strategy

Inform everyone in the museum why changes need to be made and how they can help (i.e., by changing their habits).

Keep a record of what you have done - the date it was done and where it was done.

Be certain to investigate any chemical you plan to use: that it is legal and the least invasive or least toxic method available. For example, cigarette companies find the pheromone traps provide significant control of the cigarette beetles in their factories.

Be certain that methods are properly applied. For example, a pheromone trap attracts insects, so place it at a slight distance rather than in the middle of susceptible collections; thus bugs will be attracted away rather than toward the collection.

Know what dosage (concentration) to use and in what form (liquid, powder, oil-in-water emulsion, etc.).

Know how long a treatment lasts at the temperature and relative humidity of your climate, in the sunlight, or in the dark. Be certain that it will not affect trees, plants, etc. Know how safe it is to humans (see below).

5. Evaluate the Results

Again, inspect. Monitor with sticky traps, baits, pheromone traps, or black light traps; document numbers, location, and date. Check on a regular basis (every week or every month). Survey a sample of the susceptible collection. For example, look in a different cabinet every month to inspect a different group of textiles every time.

III. How Toxic to Staff (and to Visitors) Will the Pesticide Be?

Toxic means poisonous.

Dermal toxicity refers to poison absorbed through the skin. For example, dry materials (dusts, wettable powders, granules) can be absorbed into your skin, especially on a hot, humid day.

Oral toxicity refers to poison ingested. For example, it can occur while eating or smoking or from putting your hands or your food on sprayed surfaces.

Inhalation refers to poisons breathed through your nose. For example, breathing the vapor of the pesticide (not the carrier, but the pesticide itself can cause harm).

Acute effects are measured as LD50 meaning the lethal dosage for 50 percent of the animals tested. Sometimes they are measured as LC50 meaning the lethal dosage in the air for 50 percent of the animals tested. The lower the LD50 or LC50, the more poisonous the pesticide.

Chronic Effects are how poisonous a pesticide is to an animal or human after small, repeated doses over a long period of time. (LD50 and LC50 are not a measure of chronic toxicity.)

A fumigant is a poisonous gas that kills when absorbed or inhaled. Most are highly toxic but have no residual effects.

A pesticide is a chemical or other agent that will destroy a pest or protect something from a pest. 1. A residual pesticide is a pesticide that can destroy pests or keep them from causing damage for long periods of time after it is applied (days, weeks, or months). 2. A short-term pesticide is one that breaks down almost immediately after application into non-toxic by-products.

Most chlorinated hydrocarbons (Aldrin, Dieldrin, DDT, Lindone, Chlordane) are banned in the United States and Europe. Some of these chemicals have been found in collections in museums in Europe. They are residual pesticides that have chronic effects on people and animals. Until recently, they have been widely available in Europe (in grocery stores) and in the United States. As pesticides they worked very well, but they proved to have long-lasting toxic effects.

Caution: Carbamates (Sevin, Furadan, Lannate) and organophosphates can attack a chemical in your body called cholinesterase; your nervous system will be affected. These chemicals should not be sprayed on surfaces where people might work (desks or tables in storage rooms, etc.).

IV. Will Pest Control Harm the Art Object?

It is not difficult to find out about commercial or industrial materials such as cereal grains, fruits, cinder blocks, woods, spices, and metals. Whether a museum object will be harmed is more difficult to determine. In discussing and describing infested objects with a professional pest control operator (PCO) or entomologist, use material class terms (leather, wool, softwood) and be careful to mention all composite materials (protein glue, brass fittings, silver threads).

What is best for one museum's collection will not necessarily be the best for another unless the pest, climate, conditions, and collections are exactly the same.

Appendix 5

Getty Museum Pest Management Policy

Pest Management (1994–1996)

The Getty Conservation Institute (GCI) offered several courses in pest management and control in museums. The first course, held in 1994, examined eradication procedures and was designed for conservators, collection managers, and other museum personnel responsible for overseeing pest management policies and activities within their institutions. Course topics included integrated pest management as part of an overall preventive conservation strategy; identification of insect pests and the damage they cause; methods to prevent infestations; insect pest eradication by means of chemical fumigants, inert gases, and freezing; and options for combating infestations. The course reviewed techniques for pest management and control and presented information on the use of nitrogen as a non-toxic means of eradication -- a technique that had been the subject of extensive study by the scientific program of the GCI as part of its Nitrogen Anoxia Research.

In 1996, a similar course was organized by the GCI, in partnership with the Conservation Unit of the Museums and Galleries Commission of the United Kingdom (now called*re*:source, The Council for Museums, Archives and Libraries). This course included greater emphasis on preventing infestations, rather than on responding to infestations after they occur, when chemicals extremely toxic to humans and harmful to objects in museum collections are needed. The course considered nontoxic eradication methods such as thermal control and the use of inert gases. Practical exercises included a visit to a local museum where participants were able to carry out a practice inspection with the objective of developing an integrated pest management plan, and sessions in setting up and carrying out a mock inert-gas treatment of objects.

Appendix 6

"In Situ Museum and Archive Services"

http://www.insituconservation.com/en/products/nitrogen_disinfestation_systems/hanwell zero2_system. Accessed December 2nd, 2014

ANOXIC TREATMENT FOR INFESTED ARTEFACTS AND COLLECTIONS HANWELL ZerO2



ZerO2 set to eradicate unwanted visitors from museums and galleries

The ZerO2 insect pest control solution is a revolutionary atmospheric control method, making it possible to eliminate insect pests from organic materials cost effectively and efficiently. The ZerO2 is the first product of its kind that can eradicate damaging insect pests from organic materials 100% effectively without the need for expensive chemical treatments.

The treatment process is simple and effective and can be used by in-house staff at a convenient time with minimal disruption. The oxygen scavenger Is based on oxidation of metal (iron) and has earned a reputation as a consistently made product. Simply place the applicable item(s) into the relevant container – flexicube, flexiart bag or flexitube.

Insert an oxygen sensor and scavengers then seal the bag. The oxygen sensor LED will turn green when oxygen levels have fallen and treatment is in process. Treatment usually takes 30 days to complete.

Not only is the ZerO2 system chemical-free, it's also hugely cost effective in comparison with all other insect pest control treatments. To compliment this process, the Hanwell oxygen sensor can be supplied with radio transmission, temperature and humidity options for storing items following treatment. Items stored in the containers with this environmental monitoring enables users to protect items from further infestations and other damaging parameters, such as light and ultraviolet light.

Product Features

Safe, long-term storage protection
Artefacts stored in bags are protected from long-term infestation, light and UV
Does not contain residual pesticides, such as malathion and permethrin
Does not contain harmful gases, such as methyl bromide and phosphine
Benefits
Cost effective and reliable
Stress-free, easy-to-follow method
Artefacts never leave protection of your own building
A fraction of the cost of other methods

A new weapon to help museums and galleries wipe out the damage caused by insect invasions is being launched by Hanwell Instruments Ltd.

According to research, one of the most costly problems faced by museum and art gallery managers is protecting valuable artefacts from insect pests.

Hanwell's ZerO2 device offers a cost-effective and chemical-free solution to reduce permanent damage to museum property.

Anobium Punctatum ('woodworm'), Carpet Beetle Larvae, Silverfish and the Clothes Moth have all been responsible for damage to furniture, textiles and artefacts during the last 100 years within museums.

These pests have previously been difficult to control, with museums and galleries forced to spend large sums to bring in pest control companies. This is not only an expensive option, but the remedial treatments can leave residues or harmful gases on the artefact.

The ZerO2 Alert Device created by Hanwell , successfully eradicates such pests without using damaging chemicals and can be used in-house, allowing for a more cost effective solution. Artefacts are placed within a suitable purpose built container (Flexicubes, Flexiart or Flexitube, depending on size) which hold oxygen scavenger sachets to reduce the level of oxygen inside the container, killing all insect pests.

The ZerO2 device is placed in an internal window inside the container and indicates when the oxygen level is below 0.1% with a green LED indicator, or when the oxygen is above 0.5% with a red indicator.

Once treatment is complete, the artefact can be stored in the bag, protecting it from further environmental factors including light and UV damage.

Hanwell has also designed a radio logger version of ZerO2 Alert, which enables users to receive transmitted data directly to a PC, with an additional feature to measure temperature and humidity for storage purposes.

Photo	Code	Title	Quantity
	15.01.01.003	FLEXICUBE 1 CUBIC METER BOX	1
	15.01.01.004	T488 FLEXICUBE 3 CUBIC METERS BOX	1
	15.01.01.005	T489 FLEXICUBE 5 CUBIC METER BOX	1
	15.01.01.009	FLEXIART 1 SQUARE METER	1
	15.01.01.010	FLEXIART 1 SQUARE METERS	1
	15.01.01.011	FLEXIART 3 SQUARE METERS	1
	15.01.01.006	FLEXITUBE 2.5m IN LENGTH - 500mm DIAMETER	1
	15.01.01.007	FLEXITUBE 4.5m IN LENGTH - 500mm DIAMETER	1
	15.01.01.001	ZerO2 OXYGEN SCAVENGERS (Pack x 2)	1
	15.01.01.002	HUMIDITY STABILISERS (Pack x 10)	1

	15.01.01.008	ZerO2 ALERT INDICATOR	1
	10.04.05.054	TEMPERATURE & HUMIDITY DATALOGGER HANWELL 43791-h HUMBUG	1
	15.01.00.019	HEAT SEALER HZ HOT SEAL	1

Appendix 7

Minnesota History Museum Pest Management Policy

INTEGRATED PEST MANAGEMENT PROGRAM
MINNESOTA HISTORY CENTER

I. **Goals**:

A. The main goal of the Integrated Pest Management (IPM) Program is to keep the facilities free of pests. IPM as used here connotes the control and eradication of pests that attack and damage collections of cultural and scientific materials.

The term *pests* denotes insects and other arthropods, rodents, fungus and any other creatures who do not belong inside buildings.

B. **IPM consists of the following activities**:

1. **Monitoring**: regular monitoring of the facility for the types and numbers of pests that have infiltrated the building structure and fabric;
2. **Housekeeping**: Control and careful cleanup of food wastes and keeping all areas clean of all debris that is attractive to pests;
3. **Building Maintenance**: Keeping the building fabric in good condition to prevent the ingress of pests through cracks, gaps, etc.; this includes gasketing doors and windows, keeping plants away form the exterior walls, controlling temperature and R.H. within all spaces in the structure;
4. **Eradication**: Controlling and eradicating pest species through the judicious and sparing use of chemical insecticides, fumigants, and fungicides on a regular and as-needed basis; non-chemical methods such as freezing are used whenever possible to treat individually infested

II. **Methodology**:

A. The IPM Program (hereafter referred to as the Program) at the Minnesota History Center (MHC) will consist of the following components:

1. **Monitoring**: All spaces subject to infiltration and habitation by various pest species will be monitored with glueboards, smaller blunder traps, and live traps for rodents. The contracting PCO will place the boards and collect them, and communicate the results to the Objects Conservator. The PCO will have to be accompanied by Museum Collections Dept. staff memberinto all Level B storage areas, and a Library and Archives Staff member into any storage areas on Level A. A regular schedule must be set up for inspection visits.

a. Large format floorplans of the entire building will be obtained and zones will be marked out and locations numbered.

b. A database will be set up by the Objects Conservator to keep track of the trap locations, dates of setting, and an inventory of the catch.

c. Unidentified specimens will be sent to the appropriate agency for identification. A comparative collection will be assembled by the Objects Conservator for in-house identifications.

2. **Building Maintenance**: All outside doors which lead to the Collections areas will be gasketed with floor sweeps. The exterior of the building will be inspected regularly for cracks and settling.

3. **Housekeeping**:

a.The Staff Amenities Subcommittee of the MHC Building Use Committee has made recommendations regarding food and live plants in the building in reference to staff activities:

(1) Live plants and cut flowers will be kept out of all collections use areas. They will be allowed in the Great Hall, food service and office areas in which collections are not located.

(2) Food will only be allowed in non- collections handling areas.

b. The Conservation Department will to continue to actively work with the exhibits staff to advise on pre-treatment of wood and other materials to be used in exhibits.

c. The food service areas must be kept clean and constantly monitored. Care must be taken to completely clean up after events and to prevent food from entering the Reference area on Level 2.

III. **Procedures for Collections:**

A. Upon collecting objects and materials that have been exposed to favorable conditions for pest infestation, the conservation staff will be notified and reasonable lead time given for scheduling and preparation for inspection and pest control actions, if necessary.

B. If an object is infested, the Conservation Department must be informed so a field inspection can take place and advice given as to whether the object should be accepted based on its condition. Plastic bags will be taken to the collections sites and infested (mold and/or insects) boxes will be bagged before returning to the MHC.

C. If the decision is made to accept an infested or suspected object, it will be held in the Pre-treatment Quarantine Room (B-164) near the loading dock. The objects should be bagged or wrapped in polyethylene sheeting. Decisions will be made as to which fumigant to apply and if a contractor is hired for the job. The conservation dept. has the capability to do low oxygen fumigation for smaller objects.

D. Smaller objects will be prepared (i.e. dried of excess moisture, wrapped in plastic, Pest Control Form Cl 008 will be filled out by the conservation staff, etc.) for freezing in the chest freezer in B-164. The standard process of two 48 hour cycles at -20 degrees C will be followed where applicable or modified to fit the situation.

E. Objects that are infested with mold growth will be processed and cleaned in the "Mold Room" (B-167) using fungicides and drying procedures appropriate to the materials.

F. Only after the proper quarantining and treatment procedures have been completed to the satisfaction of the Conservation Department will the objects be moved into spaces with other collections. Safe handling techniques will be employed if objects have been treated with chemicals. The MSDS's provided prior to the use of specific pesticides will be consulted to determine the specific handling techniques and equipment required. Collections staff will monitor the

IV. **Paper-based Collections:**

A. The MSS and Archives accessions are inspected on site by the staff member who is acquiring the collection.

1. plastic bags will be taken to the collections sites and infested (mold and/or insects) boxes will be bagged before returning to the MHC.
2. the Pest Control Treatment Form (CL 008) will be filled out by the MSS and Archives acquisition staff and submitted to the Objects Conservator for further action when it is deemed necessary to treat infested materials.
3. It is imperative to keep accession information on the containers holding the records during every phase of pest treatment. Pressure sensitive labels will be used on the boxes and exteriors of the bags.

B. When an infestation is observed, the Objects Conservator and MSS/Archives staff will move the boxes to B-164 (Museum Collections Quarantine holding area).

V. **Staff Education:**

A. The MHC staff will attend IPM orientation sessions conducted by the Conservation Department.

B. These orientation sessions will consist of the following informational components:

3. Introduction to IPM
    a. components (structural, cultural, etc.)
    b. goals
4. Brief description of museum pests and their biology.
5. Description of the MHC IPM procedures.
    a. monitoring
    b. chemical applications

Appendix 8

Eastern Subterranean Termite Control

Prescription Treatment® brand Pest Management Bulletin

Volume 8

Subterranean Termites: Detection and Control

The prevention and control of subterranean termites accounts for approximately 26 percent of all pest control industry revenues in the United States. In 2004, it is estimated that these termite revenues will be in excess of $2 billion. The cost to repair the damage caused by subterranean termites easily exceeds $2 billion a year. However, along with the potential business from this market segment comes the potential for liability in the form of termite damage claims and litigation. This pest management bulletin will focus on two of the most important aspects of termite management – detection and control, and their potential for causing liability to PMPs.

BIOLOGY

As social insects, termites live in groups or populations usually referred to as colonies. Depending on species, location and age of the colony, a single colony can contain from a few thousand to several million termites. Currently, colony structure is thought to be in the form of a diffuse network of satellites or nodes connected by tunnels or galleries. There is no central colony headquarters. Immature and reproductive forms can be found dispersed throughout the colony.

Linear foraging distance for subterranean termites can range from less than 10 meters to more than 100 meters. Estimated foraging area for subterranean termite colonies ranges from less than 10 square meters to several thousand square meters. Given the diffuse nature of termite colonies, their potential linear foraging distance and foraging areas, it is likely that a termite colony will feed at several different sites at any given time.

Of all the environmental factors necessary for sustaining subterranean termites, moisture is probably the most important. Subterranean termites lose moisture through their exoskeleton and, unless there is a readily available supply of moisture, they will either abandon the location or they will die. Moisture can be obtained from wet wood, soil or moisture-laden air. Wood with moisture content above 15 percent by weight may be sufficient to support subterranean termite activity and survival. Optimum temperatures necessary for subterranean termite activity range from 75° F to 95° F and will vary somewhat among species. Feeding diminishes above or below this range.

There are currently six species of subterranean termites in the genus Reticulitermes known to occur in North America. They are:

1. *Reticulitermes flavipes* (eastern subterranean termite)
2. *Reticulitermes virginicus* (dark southern subterranean termite)
3. *Reticulitermes hesperus* (western subterranean termite)
4. *Reticulitermes tibialis* (arid land subterranean termite)
5. *Reticulitermes hageni* (light southern subterranean termite)
6. *Reticulitermes arenicola* (sand-dwelling subterranean termite)

Four additional subterranean species are also found in the U.S. including:

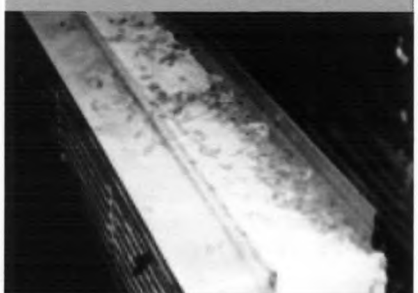
1. *Coptotermes formosanus* (formosan subterranean termite)
2. *Coptotermes havilandi* (* no common name)
3. *Heterotermes aureus* (desert subterranean termite)
4. *Prorhinotermes simplex* (Florida damp wood termite)

All 10 species listed above are capable of damaging structures – some more than others. The eastern and western subterranean termites and the Formosan subterranean termite account for the largest share of structural damage in the United States.

INSPECT

Generally, there are relatively few visible signs of incipient subterranean termite infestation in most structures. Since they are primarily soil-dwelling insects, they often enter structures completely undetected through elements of construction. It is not until they swarm or produce visible damage on or in the structure that their presence may be noticed. When subterranean termites attempt to enter a structure over an exposed structural element, such as a perimeter foundation wall or pier, they risk the drying effects of air and the possibility of attack by predators. To avoid these conditions, they construct earthen or mud shelter tubes over the surface of exposed areas. These mud tubes are common signs of subterranean termite infestation.

Mud Tube



Discarded Wings

Another sign of subterranean termite infestation occurs when large numbers of winged termites or alates swarm from the wood in an infested structure. The presence of a large number of discarded wings on the floor beneath windows or on windowsills suggests that winged termites have emerged from within the building. While it is typically thought that a subterranean termite colony producing winged reproductives is considered to be well established and usually containing at least several thousand colony members, this is not always the case. Small numbers of termites isolated above ground in structures as a result of treatment with repellent termiticides can, if sufficient moisture is available, produce swarming termites within the first year of their isolation from the original colony. The total number of termites in these isolated colonies may not exceed 200 or 300, yet are capable of producing winged reproductives.

The cryptic nature of termites and the complexity of building design and construction can make it virtually impossible to find visible evidence of infestation in some infested buildings. As a result, termite inspectors must be thoroughly trained in termite biology, building construction methods and inspection techniques before they are allowed to inspect buildings unsupervised.

Most termite inspections done today are limited in scope to the visible accessible areas of a structure and rarely, if ever, involve destructive testing such as removing wall, ceiling or floor coverings. Inspectors search for visible signs of subterranean termite activity including mud tubes, the discarded wings of alates and visible damage done by termites.

At a minimum, the tools a termite inspector should use include:

- Flashlight
- Graph paper for preparing a diagram
- Pick/probe for probing and sounding suspect areas
- Ladder for reaching overhead areas
- Moisture meter for detecting moisture from leaks and other sources
- Camera to document conditions
- Safety equipment for inspection of crawl spaces, and/or attics

PT 702

Finally, a professional subterranean termite inspector must have enough time to perform a thorough inspection. It is unlikely that a thorough professional termite inspection on even a small slab foundation home can be completed in less than 45 minutes. Larger homes with crawl space foundations may take as long as 90 minutes or longer to inspect thoroughly.

PT 707

As mentioned above, it is entirely possible for a building to be infested with subterranean termites and not have any visible signs in accessible areas. As a result, the use of termite detection stations around the exterior perimeter of the building can be an important tool for early detection of termite activity around the building. The use of Whitmire Micro-Gen's termite monitoring stations such as PT® 702 or PT 707 are ideal components of a truly integrated termite monitoring system.

A newer and more innovative method of subterranean termite control was initiated in the mid 1990s called termite baiting.

Advance® Termite Bait System

1 2 3 4 5

1. Quick-Lock™ cap
2. Termite Inspection Cartridge (TIC)
3. Termite Monitoring Base (TMB)
4. Termite Bait Station (TBS)
5. Termite Bait Cartridge (TBC)

PRESCRIBE

If termites are found during an inspection, the PMP will typically prescribe a treatment for the structure. There are a number of variables that must be considered before a treatment plan can be prescribed:

- Species of termite and the locations and extent of the infestation
- Type of foundation and building construction and environmental factors such as proximity to lakes, rivers, streams, water wells
- Soil type and landscaping practices
- Customer concerns and previous infestation and treatment history
- Potential legal and regulatory issues
- Time, tools and materials required to complete the job
- Pricing and warranty considerations

TREAT

Currently in the United States, there are two primary methods used to treat subterranean termite infestations in buildings: 1) conventional soil treatment with liquid termiticides and 2) termite baits.

Application of liquid termiticides to create a barrier between the termites in the soil and the wood (cellulose) in the building has been the primary method of treating subterranean termites for more than 60 years. Current liquid termiticides fall into one of two categories based on termite response: repellent or non-repellent. All of the pyrethroid termiticides currently used are repellent to termites and, while fully capable of killing termites, function primarily as repellents in keeping termites from entering structures.

The newer non-repellent termiticides are relatively slow acting and while they do not immediately stop termite activity in or around the structure, they ultimately cause the demise of a greater number of termites in the colony than repellents, although no definitive colonly elimination studies have been published to date.

A newer and more innovative method of subterranean termite control was initiated in the mid 1990s called termite baiting. This method uses a highly palatable food source to entice subterranean termites to feed in bait stations installed in the soil. Once termite feeding becomes established, a bait matrix containing a slow-acting termiticide is introduced into the bait station. Because termites use a form of social food sharing known as trophallaxis, termites feeding on the bait toxicant ultimately share the toxicant with other colony members during food exchange. This mode of action can lead to elimination of the colony. The active ingredients used in termite baits today include neurotoxicants, metabolic inhibitors and chitin synthesis inhibitors such as diflubenzuron and hexaflumuron.

While many structures are currently protected with conventional liquid treatments or termite baits, a large number of homes and other buildings are receiving hybrid treatments where termite baits are used along with spot applications of liquid termiticides. Other methods of termite control currently in use include treatment of above ground wood with borates, termite shields, stainless steel mesh to create physical barriers between the structure and the soil, termiticide-impregnated plastic films and particulate barriers such as sand and basaltic rock. Also in wide use, the localized treatment of termite-infested wood has become a common practice. One of the most widely used products for localized wood injection is Cy-Kick® crack & crevice® pressurized residual.

If, after a thorough inspection of a property and homeowner interview, you decide that baiting or the combination of baiting and liquids is the primary treatment technique necessary for the control of a subterranean termite infestation, you will want to select the best designed termite bait system on the market. The Advance Termite Bait System is, without a doubt, the most innovative termite baiting system available.

Installing and maintaining the Advance Termite Bait System is easy and straightforward:

1. Place station around the home at 10-foot intervals. Be sure to locate stations adjacent to any known sites of termite infestation or activity.
2. Drill holes in the soil with a gasoline-powered soil auger and 2 1/2 inch bit. Place the stations in the hole and press firmly into the ground.
3. If termites are active and/or in the structure at the time of installation, inspect the stations at 45 and 90 days from the install date and approximately every 90 days thereafter. If no termite activity is detected at the time of installation, then the first inspection is approximately 90 days after installation and approximately every 90 days thereafter. Following the initial installation, if termites are detected in the stations, the inspection interval remains approximately every 90 days.

The Spider attached to the Advance Termite Bait Station.

4. To inspect the station, remove the station cap with The Spider™ station access tool, than remove the Termite Inspection Cartridge (TIC) with the cotter pin or needle nose pliers. Termite feeding activity within the TIC can be readily detected by finding termites in the cartridge, by evidence of their feeding on the compressed cellulose tablets, and/or by the presence of mud in or around the cartridge or the Termite Monitoring Base (TMB). If no termite activity is present, replace the TIC in the bait station until the next monitoring period. The TMB does not have to be removed during routine inspection.
5. If termites are detected in the TMB or in the TIC, the TIC is replaced with an Advance Termite Bait Cartridge (TBC) containing 93 grams of 0.25% diflubenzuron. Remove the plastic wrapper around the TBC before installing the cartridge in the bait station.
6. The termite bait station is now inspected every 90 days. The TBC is replaced as necessary per label instructions. Then the TBC is replaced with a TIC and monitored every 90 days.

COMMUNICATE

In professional termite control, communication with the customer is essential and should begin prior to performing an inspection and continue throughout the termite management process. It's especially important to interview the customer to learn as much as you can about the history of the house, construction techniques used, any repairs or additions to the structure, and termite infestation and treatment history.

After your inspection, inform the customer of your findings and recommendations for treatment. Be forthcoming with the customer regarding the correction of any conditions which may be conducive to termite infestation or which may interfere with inspection or treatment of the structure. Explain these items clearly, document them on the initial inspection diagram and provide this information to the customer in writing.

Another benefit of using a quarterly baiting system such as the Advance Termite Bait System is the opportunity to communicate with the customer on a quarterly basis instead of annually, as you would with liquids. This is the time to discuss the status of the baiting process and to remind the customer of the importance of eliminating conditions that promote termite activity or interfere with the control program. It has been said that most lawsuits filed against PMPs regarding termite work are primarily due to a lack of effective communication. Don't let this happen to you. Be completely forthcoming with your customer and stay in touch. Also, don't miss the opportunity to combine termite control with Advance along with general insect control.

FOLLOW-UP

Continual follow-up is essential in any termite management program. Whether baiting or using conventional liquid treatments, the primary follow-up procedure is the post-treatment annual inspection. While termite bait systems are often inspected monthly or quarterly, this is not the same as an annual inspection of the structure for evidence of termite infestation. Annual inspections may very well be the most important inspections done on any structure being managed for termites. Thoroughness is absolutely essential.

If a re-occurrence of termite infestation of the structure is not detected during the annual inspection, it may be 12 months before another opportunity to find any re-infestation presents itself. Of course, during that time period, the level of damage may become worse and the infestation more extensive use. Use annual inspections to remind customers of their responsibility in correcting conditions conducive to infestation by subterranean termites or conditions that may reduce the effectiveness of treatment or make inspection difficult. Communication with customers about these issues is important and should always be in writing.

For additional information about the Advance Termite Bait Station, please consult our website at www.advancetbs.com.

Appendix 9

Minnesota Historical Society Pest Control Policy

What you will find here is practical information on how to preserve cultural heritage collections. The information is based on standard museum and library practice and is basic and non-technical. It emphasizes preventive care---the measures that reduce or prevent deterioration--- and focuses on a cost-effective approach to the preservation of collections long-term.

The first six topics address the general needs of all types of items. This is where you will find answers to general questions about museum practice and learn about the basic tenets of preservation. For example, at what temperature and relative humidity should collections be stored? Or what types of storage furniture are available and preferable? These six topics deal with the issues, procedures, and standards that contribute to the preservation of all types of items regardless of the materials from which they are made.

The remaining topics deal with the unique characteristics and specific needs of particular materials or groups of similar materials. This is where you will learn how to adapt standard practice to the needs of particular items depending upon their composition. For example, does a collection of wooden furniture have special temperature and relative humidity needs? Or, are there particular concerns regarding insect infestation for leather clothing items? The same subjects are addressed for each material or group of materials. These are: identification and general information; basic care and storage; special pest concerns; routine handling; display issues; mounts and supports; and cleaning and minor repairs.

It is hoped that this information will answer questions, provide guidance, and lead to improvements in the condition of collections and the continued preservation of our cultural heritage. If you have questions that are not answered here, please contact the conservation department of the Minnesota Historical Society at 651-259-3380.

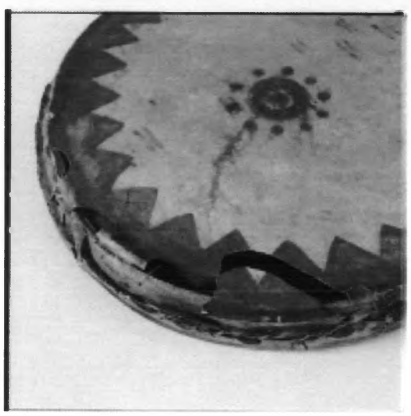
INSTITUTE of Museum and Library SERVICES

Institute of Museum and Library Services

Connecting to Collections

...The Bookshelf...

Basic Preservation Considerations

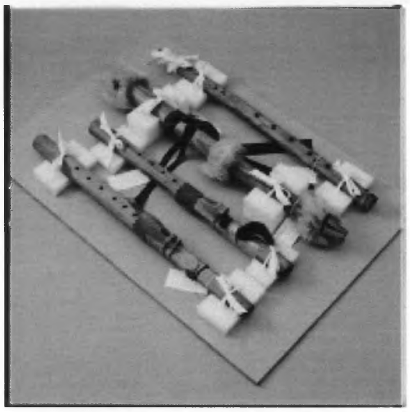


Basic Preservation Considerations [PDF]

- Temperature and Relative Humidity
- Light
- Air Quality
- Water and Fire

- Insects and Mold
- Security

Storage Containers, Supports, and Mounts



Storage Containers, Supports and Mounts [PDF]

- Types and How to choose
- Standards and considerations
- Fabrication Materials --- Paper
- Fabrication Materials --- Plastics
- Fabrication Materials --- Fabric

Storage Furniture

Storage Furniture [PDF]

- Standards and Fabrication Materials
- Types of Furniture and How to Choose

Handling Practices

Handling Practices [PDF]

- Gloves
- Handling an Item
- Moving an Item
- Damage Incident Reports
- Visitor Procedures

Cleaning Practices

Cleaning Practices [PDF]

- Storage and Display Areas
- Floors
- Shelves and Other Surfaces
- Collections' Items

Display

Display [PDF]

- Light
- Temperature and Relative Humitity
- Air Quality
- Display Cases
- Display Fabrics
- Supports and Mounts
- Display Fabrics
- Supoprts and Mounts
- Display Without Cases
- Security
- Use of Substitutes
- Loans
- Basic Display Checklist

Materials

- Paper [PDF] Such as books, maps, manuscripts, photographs, newspapers, documents, letters, maps, prints, and drawings
- Skin and Skin Products [PDF] Such as clothing, shoes, saddles, drum heads, and quivers
- Textiles [PDF] Such as quilts, clothing, and bags
- Wood and Birch Bark [PDF] Such as furniture, bowls, boats, baskets, and scrolls
- Plant Materials [PDF] Such as baskets, hats, containers, and mats
- Ceramics [PDF] Such as vessels, toys, pipe bowls, and decorations
- Metals and Alloys [PDF] Such as jewelry, vessels, and weapons
- Stone [PDF] Such as jewelry, arrowheads, rock art, sculpture, mineral specimens, and fossils
- Quills, Horn, Antler, Hair, Feathers, Claws, and Baleen [PDF] Such as clothing ornaments, jewelry, and containers
- Shell [PDF] Such as beads, buttons, jewelry, and vessels
- Bone, Antler, Ivory and Teeth [PDF] Such as tools, jewelry and decorations
- Glass Beads [PDF] Such as used in dresses, bags and jewelry
- Plastics and Modern Materials [PDF] Such as beads, buttons, utensils and decorations
- Audiotapes and Videotapes [PDF] Audiocassette tapes, videocassette tapes, and reel-to-reel tapes
- Framed Items [PDF] Such as prints, drawings, paintings, photographs and textiles

Contact

For more information regarding the project, contact

Sherelyn Ogden, Project Director
sherelyn.ogden@mnhs.org
651-259-3380

Minnesota Historical Society
Conservation Department
345 Kellogg Boulevard West
St. Paul, MN 55102-1906

INSTITUTE of Museum and Library SERVICES

The Institute of Museum and Library Services (IMLS) is the primary source of federal support for the nation's 122,000 libraries and 17,500 museums. The Institute's mission is to create strong libraries and museums that connect people to information and ideas. The Institute works at the national level and in coordination with state and local organizations to sustain heritage, culture, and knowledge; enhance learning and innovation; and support professional development. To learn more about the Institute, please visit www.imls.gov.

November 3 , 2009

Appendix 10

US Department of Agriculture Asian Longhorned Beetle Information

USDA United States Department of Agriculture
National Agricultural Library

NATIONAL INVASIVE SPECIES INFORMATION CENTER

Home | About NISIC | News and Events | Council | Help | Contact Us

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- International

Browse by Subject

- Aquatic Species
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- Animals
- Microbes
- Economic Impacts
- Laws and Regulations
- Manager's Tool Kit
- Resource Library

You are here: Home / Animals / Species Profiles / Asian Long-Horned Beetle

Animals

Species Profiles

Asian Long-Horned Beetle

Click image to enlarge

Scientific name: *Anoplophora glabripennis* (Motschulsky, 1853) (ITIS)

Common names: Asian long-horned beetle (ALB), starry sky beetle

Spotlights:

- New Pheromone Traps Lure Asian Longhorned Beetles out of Hiding (Winter 2012)
  USDA. Forest Service.
  Entomologists from the U.S. Forest Service's Northern Research Station and Pennsylvania State University have developed a pheromone trap that lures Asian long-horned beetles out of hiding. Although it is not a treatment that can kill lots of beetles, this new trap is a major step forward in being able to detect the beetle. It may be used for finding outliers and hidden infestations in quarantine zones and standing sentry in high-risk areas.
- USDA Urges Residents to be on the Lookout for the Asian Longhorned Beetle: Beetles Expected to Emerge in July (Jun 29, 2011; PDF | 56 KB)
  USDA. APHIS. Plant Protection and Quarantine.
  APHIS is asking for the public's help in detecting and preventing the spread of Asian Longhorned Beetles (*Anoplophora glabripennis*), a serious pest of hardwood trees. To date, the beetle has caused the destruction of more than 72,000 hardwood trees in the U.S. alone. See ALB Beetle Detectives Identification Sheet (PDF | 883 KB) and report your findings at Beetle Busters.

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Animals

- Species Profiles
- Databases
- Discussion Groups
- Economic Impacts
- Educational Resources
- Image Galleries
- Frequently Asked Questions
- Management
- Publications
- What You Can Do

Media Help

To view PDF files you must have Adobe Acrobat Reader installed on your

Appendix 11

Excerpt from Morse, Joseph. 2010, Trichogrammatidae

Trichogrammatidae are parasitic on the eggs of other insects. In order to complete development their adult size can be no larger than a single insect egg, and often multiple individuals will develop in a single egg making the emerging adults but a fraction of the size of their host. Trichogrammatidae are therefore among the smallest known insects, ranging in size from 0.2 – 1.5 mm.

Certain genera such as *Trichogramma* are known to parasitize eggs of several insect orders, whereas other genera are apparently restricted to a single host order. The eggs of Hemiptera (true bugs, leafhoppers, etc.) are parasitized by the largest number of genera (e.g. *Aphelinoidea, Paracentrobia,* and *Ufens*), though Coleoptera (beetles) and Lepidoptera (moths and butterflies) eggs are also utilized by several genera. Most trichogrammatids parasitize eggs placed in or on plant tissues. Several genera (e.g. *Hydrophylita, Lathromeroidea* and *Prestwichia*) parasitize eggs of aquatic insects and have been reported to swim underwater in search of hosts.

A few genera of Trichogrammatidae are of interest for use in biological control. *Trichogramma* has received the most attention from applied entomology because its members parasitize numerous pest Lepidoptera and can be mass propagated and released with relative ease. *Trichogramma* has been the world's most widely used arthropod for augmentative biological control programs.

Recognition
Trichogrammatidae are distinguished from other Chalcidoidea by their 3-segmented tarsi. Other features which help to distinguish trichogrammatids include:

- Body shape compact, less commonly elongate, but always without a distinct constriction between mesosoma (abdomen) and metasoma (thorax).
- Body light yellow to dark brown, often a combination of both, less commonly orange or red, almost never metallic.
- Cuticle smooth to moderately sculptured.
- Flagellum with 2-9 (usually 3-7) segments, including 1 or 2 anelli (rarely 3), 0-2 funicular segments, and 1-5 claval segments.
- Antenna sexually dimorphic (different between sexes) in several genera.
- Toruli at lower margin of eyes
- Pronotum short, not obvious from above.
- Forewing varying from extremely narrow and strap-like, to very broad and only slightly rounded apically, occasionally wingless or shortwinged.
- Wing venation relatively short, usually not reaching much beyond apical half of wing.
- Postmarginal vein almost always absent (extremely short if present).
- Distribution of discal setae in both forewing and hindwing variable, but commonly arranged in distinct lines.

Diversity
The Family Trichogrammatidae currently consists of about 800 species in ca. 84 genera worldwide. The family is known from throughout the world, with representatives known from all vegetated terrestrial habitats. With the possible exception of Ittysella and *Brachyufens*, none of the recorded genera is restricted to the Nearctic region. Six genera, however, are recorded only from the New World (*Brachista, Lathrogramma, Pintoa, Trichogrammatomyia, Xenufens,* and *Zagella*). It is premature to speculate on relative habitat diversity. However, limited collections in the Nearctic region suggest that generic and species diversity is greater east of the Rocky Mountains and is perhaps greatest in the southeastern United States.
Although the Nearctic region contains few if any endemic genera, endemicity at the species level may be considerable. Several genera such as *Chaetostricha, Paracentrobia, Mirufens,* and *Zagella* are represented by virtually undescribed faunas. To a lesser extent this problem even extends to Trichogramma, in spite of this genus' importance to applied entomology. Likely due to their small size and soft-bodied nature and the subsequent need for specialized collecting techniques, this family has been inadequately sampled throughout the world and collections required for comprehensive taxonomic studies do not yet exist. It is clear that we currently know but a fraction of the true diversity of the Trichogrammatidae, and conservative estimates indicate that there may be more than 4000 more species remaining to be described. Consequently, most material cannot be identified to species, and in many cases

cannot even be accurately ascribed to any current genus. It is likely that generic concepts will change with continued taxonomic work, with certain genera being sunk and new ones erected. The confusion still present in the Trichogrammatidae can only be alleviated with further collecting efforts and the necessary taxonomic work.

Appendix 12

Excerpt from "List of Termite Species"

Termites (Isoptera) of the World

Family / Subfamily	# Genera	# Species
Termopsidae	5	20
Hodotermitidae	3	19
Mastotermitidae	1	1
Kalotermitidae	22	419
Rhinotermitidae	14	343
Serritermitidae	1	1
Termitidae		
Macrotermitinae	14	349
Nasutitermitinae	91	663
Amitermitinae	17	295
Apicotermitinae	43	202
Cubitermitinae	28	161
Termitinae	43	288
Totals	**282**	**2,761**

). Roonwal (1962). Krishna (1961). Araujo (1977). Zoological Record

Appendix 13

Diatomaceous Earth for Pest Control

DIATOMACEOUS EARTH FOR PEST CONTROL.

By William Quarles

Least toxic physical and chemical solutions are often part of an IPM program. Various forms of amorphous silica are commonly used as part of this strategy. Diatomaceous earth and silica gel are used in various physical formulations with or without added pesticide. The type of silica and the formulation depend on the target pest. In this issue advantages and disadvantages of diatomaceous earth are discussed. In July the merits and uses of silica gel will be outlined.

Diatomaceous earth (DE) is a non-toxic insecticide that is used for protection of stored products, and to control pests of the home and garden. Organic gardeners like it because it is a natural product that poisons neither the earth nor people. Pest control operators (PCOs) like it, because diatomaceous earth can be used to treat wall voids and other inaccessible regions of a house in order to deny harborage to pest insects. Also, PCO's that use least-toxic products are able to address homeowner concerns about poisons in a positive way.

Diatomaceous earth is obtained from deposits of diatomite - fossilized sedimentary layers of tiny phytoplankton called diatoms, many of them originating at least 20 million years ago in the lakes and seas of the Miocene (see Box A for more information on diatoms). The developing North American continent was full of these organisms that ingested dissolved silica and converted it into a highly ordered shell. Diatoms that lived in prehistoric seas are now mined mostly in Lompac, California as Celite ® and fossilized freshwater species are found in such places as California, Oregon, Nevada and Arizona (Cummins 1975).

Whether marine or freshwater fossils are better for insect control work has been recently debated. Freshwater fossils met with early commercial success, and are easier to apply without clumping or caking. Any diatomaceous earth with a large oil absorption capacity, though, is a candidate for use as an insecticide. Ideally, it should be a high purity amorphous silica of a uniformly small (less then 10/u) particle size, that contains very little clay, and less than 1% crystalline silica. The diatomite should be properly milled and ground, the diatoms well-separated, and if possible, physically intact (Katz 199aa; Calvert 1930; Allen 1972). Any product registered with the EPA has to meet the proper standards. This kind of material is easier to obtain from freshwater fossil sources because much of the marine diatomite is calcined (glassified by high temperatures) in order to improve its filtration characteristics (Calvert 1930).

Calcined fossils are often sold for use in swimming pool filters. Such material has little absorptive power, and