EFFECTIVENESS OF ENTOMOLOGICAL COLLECTION STORAGE CABINETS IN MAINTAINING STABLE RELATIVE HUMIDITY AND TEMPERATURE IN A HISTORIC MUSEUM BUILDING

Hanna Szczepanowska,[1] Floyd W. Shockley,[2] David G. Furth,[2] Patricia Gentili,[2] Darnell Bell,[3] Paula T. DePriest,[1] Marion Mecklenburg,[1] and Catharine Hawks[4]

[1]*Smithsonian Institution, Museum Conservation Institute (MCI), Suitland, Maryland 20746, USA*
[2]*Smithsonian Institution, National Museum of Natural History (NMNH), Department of Entomology, Washington, DC 20013, USA*
[3]*Smithsonian Institution, Office of Facilities Engineering and Operations (OFEO), Washington, DC 20013, USA*
[4]*Smithsonian Institution, National Museum of Natural History (NMNH) Research & Collections, Washington, DC 20013, USA*

Abstract.—Maintaining a stable environment is critical to long-term preservation of museum collections. The objective of this project was to determine how well storage cabinets buffer conditions in an environment with highly fluctuating relative humidity and temperature. Storage cabinets in the Insect Collection housed at the Smithsonian Institution's National Museum of Natural History were evaluated during a 6-mo study. The Smithsonian's Museum Conservation Institute (MCI), in collaboration with the National Museum of Natural History (NMNH) and the Office of Facilities Engineering and Operations (OFEO), collected environmental data within six randomly selected museum cabinets, as well as the ambient conditions in the three building zones in which they were located. Staff used an ultrasonic leak detector to identify potential leaks (sites for air exchange) and Elsec 764 dataloggers to monitor interior relative humidity (RH) and temperature (T) for each cabinet. OFEO engineers supplied the building's environmental data, collected via ethernet Veriteq (now Vaisala) monitors in all three zones and compiled monthly. The data from the ambient conditions were compared with readings from the cabinet interiors. Although T remained relatively stable, ranging from 21°C to 23°C in both the ambient environment and inside the cabinets, ambient RH ranged from 10% to 60%, while the RH inside the cabinets averaged from 38% to 45%, with the exception of one cabinet that was slightly out of the range. This demonstrates that cabinets can be highly effective in protecting collections from large fluctuations in RH.

Introduction

Architecturally complex and historic buildings such as the Smithsonian Institution's National Museum of Natural History (NMNH) building (hereafter NHB) often present challenges in maintaining stable environments for the storage and long-term preservation of museum collections. The central part of NHB was completed in 1910, while the East Wing and East Court additions where the National Insect Collection (NIC) is housed were completed in 1962 and 1999, respectively. Consequently, these building expansions resulted in a patchwork of environmental systems that have been upgraded at different times over the years.

In the present study we surveyed environmental conditions inside storage cabinets of the NIC in response to concerns that the building did not provide optimal stability of conditions for collection storage. Depending on the type of collection, high or low relative humidity (RH) can lead to pest problems and can cause physical deterioriation of natural history objects. The Smithsonian Institution has adopted collection environment target ranges of 37–53% RH and 20–25°C for collections (Erhardt and Mecklenburg 1994, Mecklenburg et al. 2004, Michalski 2007).

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This study was a two-phase project, first initiated in 2008 and completed in 2012. Phase I (initiated by two of the coauthors: Furth and Mecklenburg) focused on characterization of the ambient environment in the collection ranges and preliminary evaluation of cabinets based on their structural characteristics. With that objective in mind, 12 cabinets of differing construction and vendors were selected and monitored over a 2-mo period from mid-August to mid-October 2009. Relative humidity and temperature (T) were recorded from inside the cabinets and in the ambient collection ranges. The results of Phase I demonstrated large fluctuations in RH in the ambient environment, ranging from 15% to 60%, and minor fluctuations, ranging from 40% to 45% inside all tested cabinets, regardless of cabinet type. The T, however, remained nearly constant at 21°C during Phase I testing. The findings of Phase I then served as a guide in selecting cabinets and cabinet range locations for a more systematic and controlled study undertaken in Phase II. In this second phase, we evaluated the performance of six carefully selected storage cabinets to determine their effectiveness in buffering RH fluctuations compared to the ambient environment.

In addition, each cabinet was also tested using an ultrasonic leak detector to evaluate each cabinet's air tightness and possibly explain any discrepancies in a particular cabinet's ability to maintain stable relative humidity and temperature. Ultrasonic leak detection has been utilized since 1998 for testing air tightness of gaskets and effectiveness of clean rooms, but its application in the museum field is relatively novel. Consequently, there are no established standards about what degree of deviation from a baseline reading is considered acceptable or unacceptable for natural history collection cabinets. Air exchange ratios for storage cabinets and display cases, however, have long been considered as playing a role in maintaining desired internal environments for preserving collections (Calver et al. 2005; Thickett et al. 2005, 2008). These authors emphasized not only the need to prevent the external environment from affecting the stability inside the cabinets, but also the need for a small amount of air exchange to prevent the potential build up of damaging products resulting from offgassing inside the cabinets. Recent research on air exchange rates for museum cabinets suggests that a rate of one exchange every two to three days provides a good enclosure that aids in maintaining stable conditions without being so tight that it jeopardizes collections via internally generated pollutants (Calver et al. 2005).

Materials and Methods

The Building

Two air-handling zones within the NHB, representing three different locations of the NIC, were monitored in Phase II of this study: 5th floor East Court (5EC), 6th floor East Court (6EC), and 5th floor East Wing (5EW). None of these locations or any of the air-handling zones employ intentional seasonal humidification as part of normal building operations. The RH and T data were continuously collected via a real-time Vaisala monitoring system, recording data at 30-min intervals from 1 August 2011 to 1 February 2012. This monitoring is part of the building management system operated by OFEO, and the loggers used in this phase of the study are permanently mounted in the collection ranges. Data were downloaded via ethernet connection and then compiled and graphed monthly using Vaisala's proprietary software, viewLink.

Storage Cabinets

For this study, six metal cabinets were selected in different building zones based on Phase I data for potential zone RH fluctuations beyond the acceptable Smithsonian

Figure 1. Typical entomological cabinetry in the National Insect Collection. Cabinets in the East Court of the Natural History Building are mounted on moving compactor storage compactors (left) to maximize storage capacity, whereas those in the East Wing are stationary and arranged in aisles (right).

standard range. Three of the cabinets were double-door cabinets, and the remaining three were single-door cabinets (Fig. 1).

Besides the obvious differences in number of doors and capacity, the double-door cabinets have recessed door handles with a rotating circular back plate (Fig. 2), whereas the single-door cabinets have a different kind of nonrecessed handle that does not have a similar back plate. All cabinets selected for Phase II had intact gaskets around the door seals, so there was reasonable expectation of a good seal between the ambient and internal environments of all cabinets.

Each cabinet contained an equal number of collections drawers (14), which are made of coated wood with a tight fitting glass top. Inside each wooden drawer were various sizes of archival unit trays with insects pinned into a polyethylene foam substrate (Fig. 3).

Monitoring Instruments

The Smithsonian's Museum Conservation Institute (MCI) provided 12 Elsec 764C dataloggers, manufactured by Littlemore Scientific, for monitoring of the internal environment of the cabinets selected in Phases I and II. Elsec dataloggers record RH and T, among other environmental parameters, and are favored for their small size, reliable monitoring (given proper calibration), and relatively long battery life. Two dataloggers were placed in each cabinet, one in the top and another at the bottom of the cabinet to detect any potential within-cabinet variation. Data were collected at 1-hr intervals over the 6-mo period from 1 August 2011 to 1 February 2012. Recorded data were downloaded at the end of the project via an infrared reader that connects through standard computer USB port. The results were graphically produced in RView, Elsec's proprietary software, and then exported as Excel data files for further analysis.

To test for areas of potential air exchange between the ambient and interior cabinet environments, cabinets were analyzed with a portable, SDT 170 ultrasonic leak detector, provided by the NMNH Collections Program. Ultrasonic waves are generated by an SDT

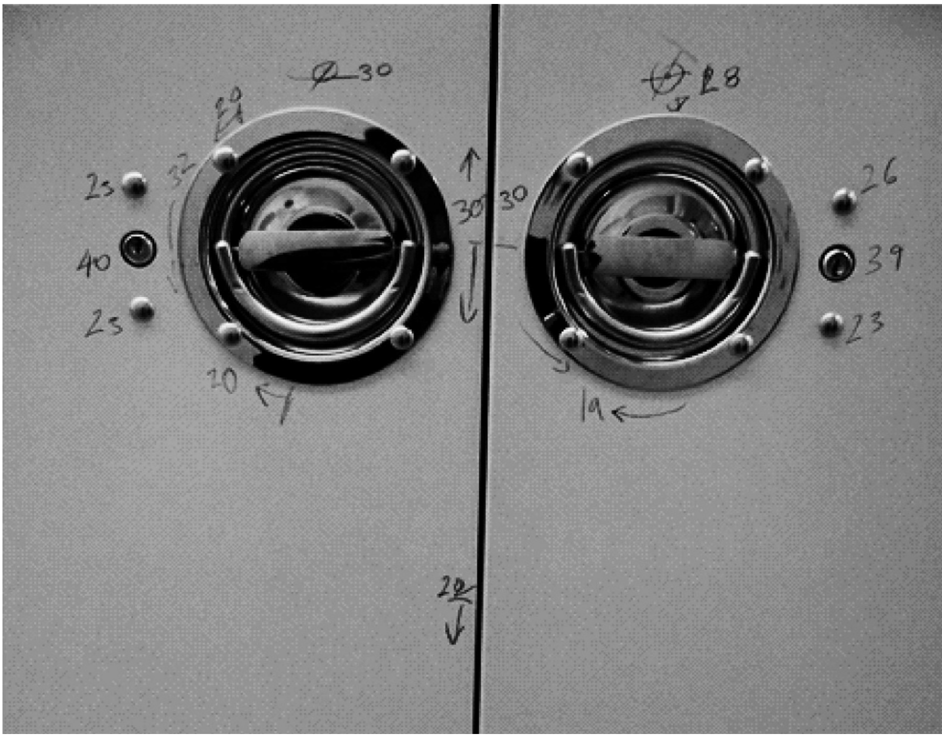

Figure 2. Cabinets marked after testing with an ultrasonic leak detector, which records "leaks" as dBmV readings of sound escaping from various parts of the cabinet. The sound was produced by an ultrasonic emitter placed in each cabinet. Readings were recorded directly on the cabinets using a wax pencil.

200 nW bi-sonic transmitter that was sealed inside each cabinet prior to deployment of the Elsec dataloggers. Ultrasonic waves are beyond the range of human hearing (>20 kHz), so the SDT 170 converts them to corresponding audible sounds and measures them as decibels (see SDT International 2012). The decibel level is reported on an LCD and manually recorded. A reference "baseline" was established by measuring ultrasonic waves that passed directly through the solid metal areas of the cabinet doors where no cutouts or fixtures were located. The flexible sensor permitted measurements in corners, near the door handles and near the hinges. During this process, the decibel readings were recorded directly onto the surface of the cabinet using a wax pencil (Fig. 3). The principle behind this testing is that the decibel levels correspond to air leakage from the cabinets, identifying possible sources of air exchange between the cabinet interiors and the environments in the surrounding spaces.

Results

The Building Environment

On the basis of our findings in Phase I, we anticipated large fluctuations of RH in the building environment. Over the 6-mo period of measurements, there were major fluctuations in RH in all three collection locations (Fig. 4).

The maximum-recorded value of RH in all three areas remained within a range of 50–60% over most of the 6-mo period, dropping below 50% in December 2011 and January 2012 for 5EC and in January 2012 for 6EC, and exceeding 60% in August 2011 for 5EW.

Figure 3. Pinned entomological collections are typically stored dry in foam-bottomed unit trays that are themselves housed inside tightly sealed glass-topped wooden drawers that are arranged in cabinets.

However, significant drops in minimum values of RH were noted in all three areas starting in October 2011 and continued until the end of the monitoring period. Average RH levels tended to fluctuate greatly, regardless of location, with high standard deviations (Table 1; Figs. 5–7). In contrast, temperature remained nearly constant across all locations, remaining between 21.6°C and 22.5°C throughout the same period (Table 1; Figs. 5–7).

Storage Cabinets

Average RH levels remained within a range of 37.6–44.8% with relatively low standard deviation (Table 1). With the exception of cabinet no. 4 located in 5EW, all of the cabinets maintained RH within the ranges prescribed by Smithsonian standards (Figs. 5–7). Interestingly, RH remained fairly high inside the cabinets relative to the ambient RH in the collection ranges, even when the ambient RH declined at the end of the study. Dataloggers inside the storage cabinets recorded very stable T, between 21.3°C and 22.7°C (Table 1; Figs. 5–7).

While the RH remained relatively stable within most of the cabinets, cabinet no. 4, located in 5EW, showed the greatest fluctuation in RH (24–44.5%) and an unusual decline in the RH in the last months of the trial period, mirroring declines in the ambient RH (Fig. 6).

Examination of the ultrasonic leak detector results (Table 1) demonstrated that cabinet no. 4 had a much higher degree of air movement from and to the cabinet due to larger openings in the cabinet (50 dB, at some sites), which was higher than that of the other cabinets. The baseline reading of 20 dB for cabinet no. 4 is much higher than that for the other cabinets, possibly reflecting a general difference in the gauge of steel used in construction of the cabinet. The average overall readings for cabinet no. 4, at 32.0 ± 8.1 dB, is higher than that for the other cabinets as well. The level of air movement for all cabinets was greatest in the areas of the hardware, such as door handles and door label holders, not along the door closures and gaskets (Table 1).

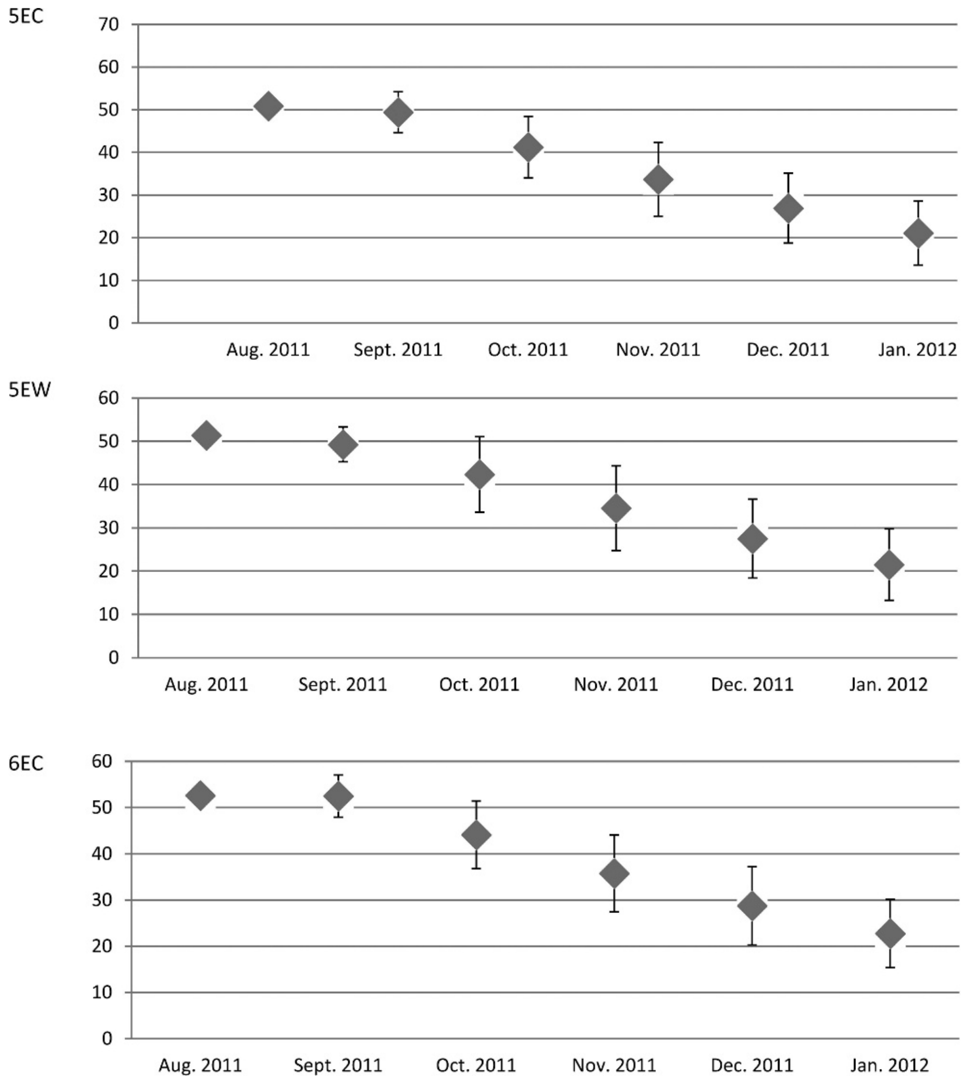

Figure 4. Monthly average relative humidity (± standard deviation) in the three monitored zones of the Natural History Building, during the 6-mo period of this study.

Discussion

The effectiveness of storage cabinets in maintaining a stable internal RH despite fluctuating ambient RH was clearly demonstrated over the 6-mo period of Phase II. Despite unusual fluctuations in one cabinet (no. 4), potentially linked to more sites of air movement based on the results of the ultrasonic detector, the internal environment in each of the cabinets was still decidedly more stable that the ambient environment. Based on these results, we can reasonably conclude that storage cabinets are useful for protecting biological collections in large historic buildings where the building architecture and air-handling systems may offer a limited degree of humidity control. In the single case where a cabinet failed to provide a stable RH compared to the ambient environment (cabinet no. 4), ultrasonic leak detection provided clues suggesting that the higher degree of fluctuation in that cabinet might be due to the construction of the cabinet.

Table 1. Sample cabinets selected for this study, including their location in the building zones, the data from each Elsec 764C datalogger units in the cabinets, where those units were located within the cabinet and the average relative humidity (RH) and temperature (T) in the cabinets and in the ambient collection ranges; data from Phase II. Finally, the results of the ultrasonic leak detector testing (a relative measure of air exchange) are also shown for each cabinet, expressed in dBmV.

			Cabinet		Ambient		Ultrasonic detector		
Cabinet	Location	Elsec location	Average T (°C ± SD)	Average RH (% ± SD)	Average T (°C ± SD)	Average RH (% ± SD)	Range (baseline)	All average (dBnV ± SD)	Hardware average (dBnV ± SD)
1	5EC	Top	22.5 ± 0.5	44.8 ± 0.9	22.5 ± 0.6	36. 2 ± 13.0	10–40 (10)	19.9 ± 6.7	29.0 ± 9.5
		Bottom	22.3 ± 0.5	44.1 ± 0.7					
2	6EC	Top	21.7 ± 0.4	38.7 ± 1.2	21.5 ± 0.4	38.3 ± 13.2	15–47 (13)	28.6 ± 9.5	35.6 ± 7.2
		Bottom	21.5 ± 0.3	39.1 ± 1.2					
3	5EW	Top	21.1 ± 0.3	41.9 ± 1.0	21.6 ± 0.3	36.7 ± 13.5	17–50 (15)	26.3 ± 9.3	26.2 ± 6.5
		Bottom	20.7 ± 0.3	44.2 ± 0.5					
4	5EW	Top	22.7 ± 0.7	37.6 ± 2.8	21.6 ± 0.3	36.7 ± 13.5	20–50 (20)	32.0 ± 8.1	25
		Bottom	21.2 ± 0.3	39.4 ± 3.8					
5	5EW	Top	22.7 ± 0.9	38.0 ± 0.9	21.6 ± 0.3	36.7 ± 13.5	18–20 (11.5)	19.3 ± 1.2	NA
		Bottom	21.8 ± 0.4	40.4 ± 0.8					
6	5EW	Top	22.5 ± 0.7	37.6 ± 0.6	21.6 ± 0.3	36.7 ± 13.5	16–23 (14)	18.3 ± 4.0	16
		Bottom	21.6 ± 0.4	39.8 ± 0.7					

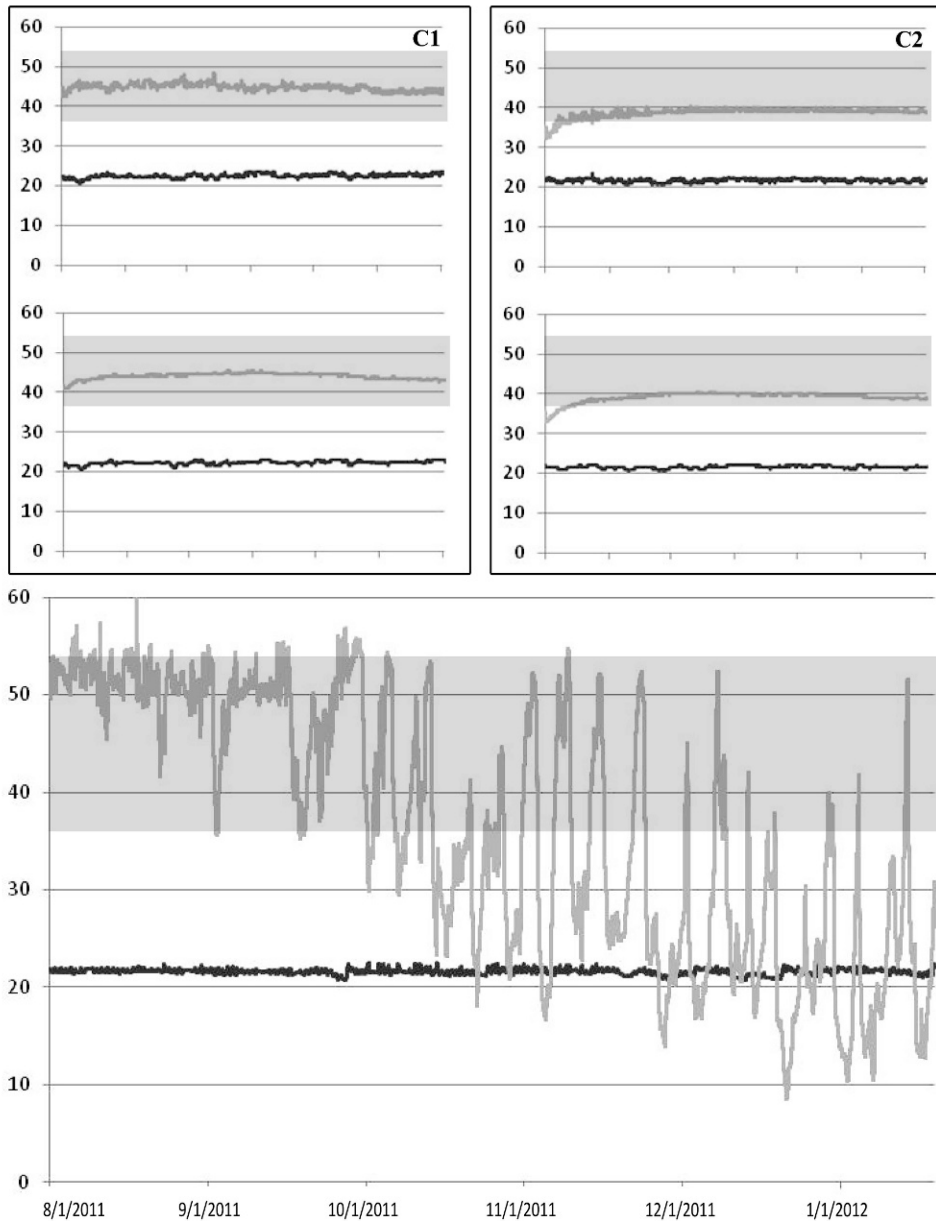

Figure 5. Temperature and relative humidity measurements from the ambient environment of the East Court of the Natural History Building over the 6-mo testing period (lower graph). Upper graphs show the conditions inside the cabinets in that zone (C1 and C2) during that same period. Uppermost graph displays data from the Elsec monitor placed in the top of the cabinet while the lowermost graph displays data from the one placed in the bottom. Gray bars = Smithsonian target range for relative humidity (45% ± 8%).

Not surprisingly, on the basis of the results of Phase I, we found that the building systems were much more effective at maintaining a stable temperature during Phase II as well, with temperatures in the collection ranges and the cabinets not differing and remaining relatively stable at ~21°C during the 6 mo of testing. Unfortunately,

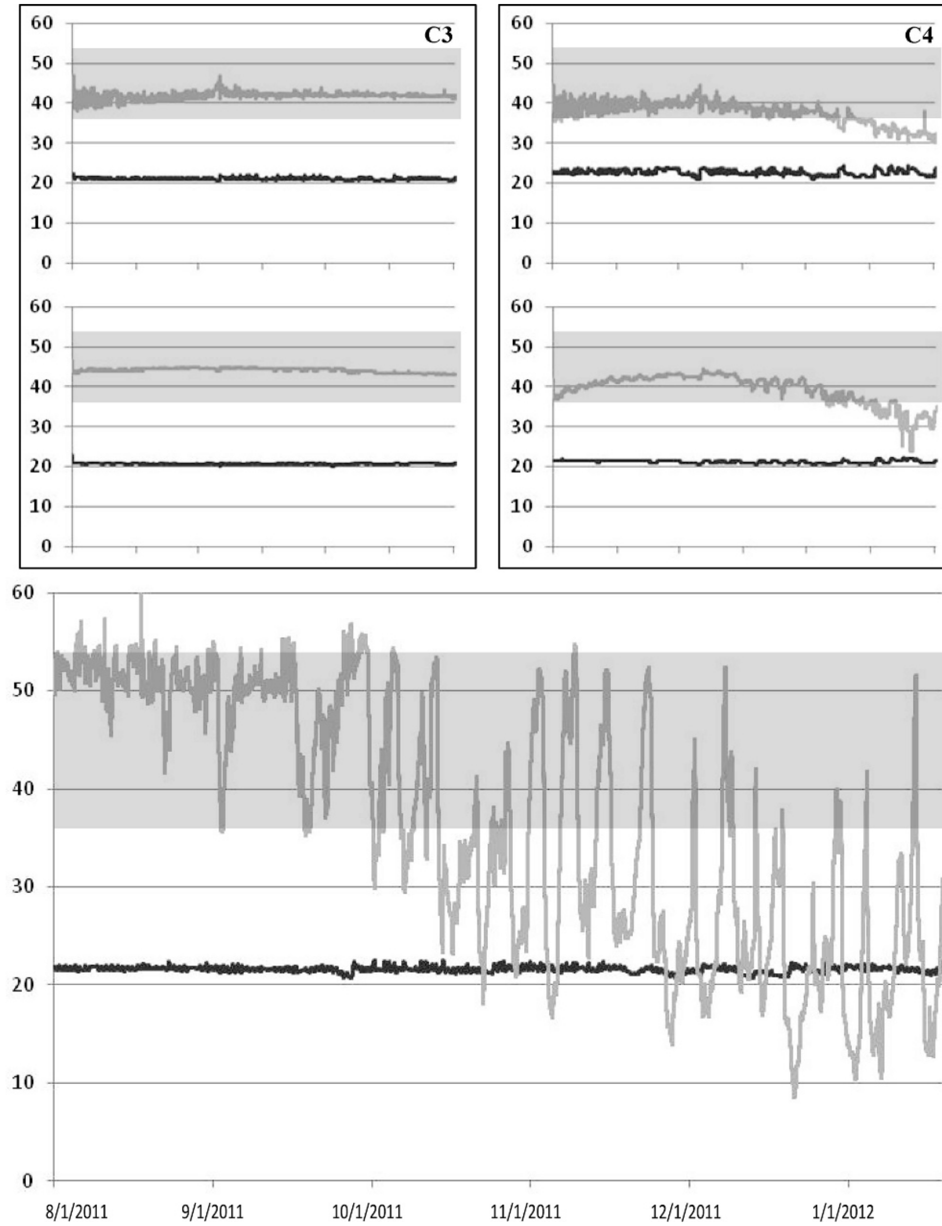

Figure 6. Temperature and relative humidity measurements from the ambient environment of the 5th floor of the East Wing of the Natural History Building over the 6-mo testing period (lower graph). Upper graphs show the conditions inside the cabinets in that zone (C3 and C4) during that same period. Uppermost graph displays data from the Elsec monitor placed in the top of the cabinet while the lowermost graph displays data from the one placed in the bottom. Gray bars = Smithsonian target range for relative humidity (45% ± 8%).

because there were no detectable differences between the ambient and the internal environment of the cabinets in Phase I or II, it is impossible for us to draw any conclusions about the ability of entomological cabinetry to buffer fluctuations in temperature.

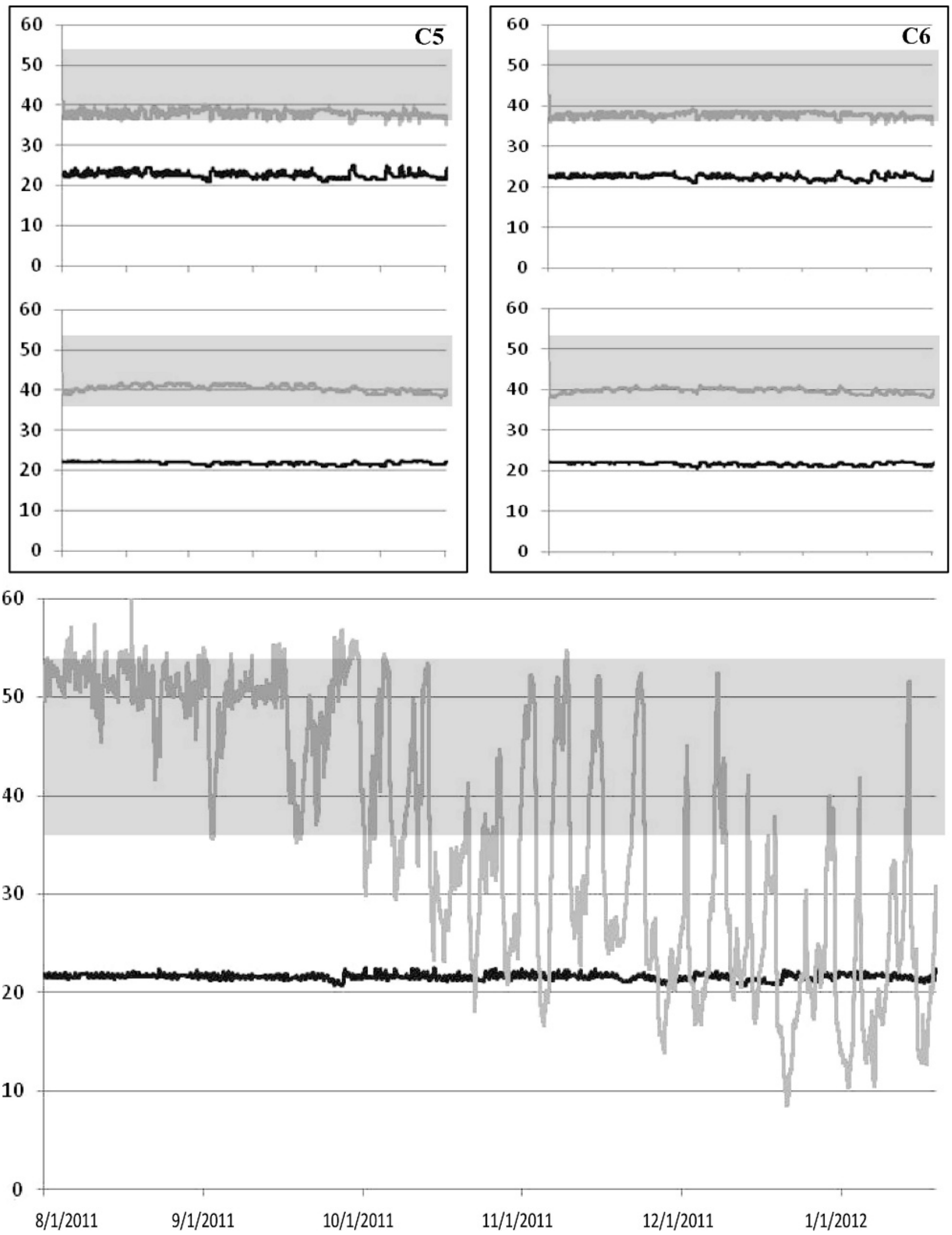

Figure 7. Temperature and relative humidity measurements from the ambient environment of the 5th floor of the East Wing of the Natural History Building over the 6-mo testing period (lower graph). Upper graphs show the conditions inside the cabinets in that zone (C5 and C6) during that same period. Uppermost graph displays data from the Elsec monitor placed in the top of the cabinet, and the lowermost graph displays data from the one placed in the bottom. Gray bars = Smithsonian target range for relative humidity (45% ± 8%).

Overall, our findings support the NMNH's commitment to providing modern cabinetry for natural history collections, helping manufacturers improve cabinet designs and cabinet seals, requiring manufacturers to provide data on air exchange rates, and monitoring temperature and RH as major factors in protecting sensitive natural history collections. Most important, our data demonstrate that additional buffering of collections is not necessary to maintain stable relative humidity as long as they are housed in reasonably well-sealed entomological cabinets.

Acknowledgments

This project relied on successful collaboration between four different units within the Smithsonian Institution: the MCI, the NMNH Department of Entomology, the NMNH Collections Program, and OFEO. Exclusion of six storage cabinets from use for 6 mo was necessary to prevent corruption of data collection, and we thank the Department of Entomology staff for their patience during this testing period. We also thank the two anonymous reviewers who offered many helpful suggestions on an earlier draft of this manuscript.

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