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The Environment of the Bowdoin College Museum of Art

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Abstract: Conservation of artifacts is a major concern of museum curators. Light, humidity, and air pollution are responsible for the deterioration of many artifacts and materials. We present here an exploratory analysis of humidity and temperature data that were collected to document the environment of the Bowdoin College Museum of Art, located in the Walker Art Building at Bowdoin College. As a result of this study, funds are being sought to install a climate control system.

Key words: EDA, exploratory data analysis, smoothing.

1. Introduction

Museums are entrusted with the preservation of important artifacts and materials. While the conservation of objects has a long history, recent attention has focused on the need to control the museum environment to minimize the deterioration of collections. Curators of museums are particularly concerned with the damaging effects of light, humidity, and air pollution. Many museums were built before such environmental concerns were recognized. Thus those museums must assess their environments and determine the most appropriate ways to modify them to protect the specific collections that they house.

Bowdoin College is a small liberal arts college which has a student body of about 1,600 undergraduates. The art collection at the College was started in 1811 when James Bowdoin III bequeathed 70 paintings and a portfolio of Old Master drawings that had come from Europe. This established one of the oldest college art collections in the United States. Its current collection, containing more than 14,000 objects, is housed in the Walker Art Building, designed by Charles Follen McKim and opened in 1894 on the Bowdoin College campus in Brunswick, Maine. Maine, the northeastern most state in the union, is heavily forested with many lakes and a long coastline, giving it its reputation as "Vacationland". While the climate varies throughout the state, winters in Brunswick tend to be cold and snowy while summers are warm with occasional periods of high humidity. The fifty year daily averages for January and July, the coldest and warmest months, are 20.6°F and 68.5°F respectively.

Beginning in the early 1980's, the main concerns about the Walker Art Building environment were about humidity and temperature. The museum staff established the ideal target humidity level for the collections to be between 45% and 65%. A temperature of between 68°F and 72°F was determined to be comfortable for people working in and visiting the museum. These ranges are consistent with general guidelines given in references such as Thompson (1986) and Appelbaum (1991). For current thinking about conservation guidelines, see the CoOL (Conservation OnLine) website (www.palimpsest.stanford.edu).

Several years later the museum staff decided to study the museum environment in a systematic way to document its temperature and humidity levels, and data were collected over a two year period. In this article we present an exploratory analysis of these data and discuss the conclusions drawn about the museum environment and their consequences for the College.

2. The Data

The Walker Art Building has a rotunda, galleries, offices, storage rooms and an Art Preparation Room. Data on humidity and temperature were collected in the rotunda, 8 galleries, 4 storage rooms, the Art Preparation Room, and outside the museum by the museum staff using a sling psychrometer. This instrument consists of two thermometers called the dry bulb and the wet bulb. The dry bulb reading gives the ambient temperature in degrees Fahrenheit, while the wet bulb reading gives a temperature that is lower by an amount that depends on the relative humidity. We recorded the wet and dry bulb temperatures and then converted them to a relative and a specific humidity. Readings were made on 143 days in the first year and 164 days in the second, sometimes twice a day. This resulted in 154 and 178 data values in years one and two respectively. Unfortunately readings were not necessarily taken at all locations so that the number of data values depends on the location.

For the following analyses we used data for year one that were collected at each of the following locations in the museum, see Table 1. (Data for year two were kept for verification purposes.)

The relative location of these rooms is shown on a map of the museum that can be found at www.bowdoin.edu/artmuseum. The storage rooms are not shown for security reasons. In our discussion we will often refer to the Bowdoin Gallery, although data for each of the above locations were analyzed in a similar manner. We note that the Bowdoin Gallery is above grade and has two external walls on the north and east sides of the Walker Art Building. The downstairs rooms are all semi-below grade, the only exception being the Temporary Exhibition Gallery

Table 1: Data for locations in the museum

Upstairs:	Bowdoin Gallery	Boyd Gallery
	Rotunda	Walker Gallery
Downstairs:	Art Preparation Room	Becker Gallery
	Halford Gallery	Homer Gallery
	20th Century Gallery	Temporary Exhibition Gallery
	Object Storage	Paintings Storage
	Publications Storage	

which is completely below grade.

One measure of the extent to which each location is a "problem" is the percentage of the time that relative humidity and temperature readings are below or above the target ranges. These percentages are given in Table 2 for all locations. It is clear from these percentages that the rooms in the museum did not conform well to the ideal. The relative humidity was outside the target range over 40% of the time for all rooms except Object Storage, the discrepancies being predominantly on the low side. The temperature in the museum was outside the comfortable range over 50% of the time.

While these percentages indicate that the museum's environment is not ideal, they do not give us any idea of the magnitude of the problem, nor do they give us an understanding of the way in which the environments in the different rooms are related to each other and to conditions outside. We address these issues in the analyses that follow.

3. The Analyses

3.1 Room profiles

The earlier description of the weather in Brunswick suggests that both humidity and temperature will show a strong seasonal effect. Figure 1 shows the relative humidity and temperature readings for the Bowdoin Gallery over the year. Horizontal lines indicate the target conditions mentioned above, and vertical lines mark the approximate end and beginning of the heating season. The Walker Art Building is not air-conditioned as is typical of older buildings in Maine. A smooth curve that follows the overall pattern of the data was superimposed on each plot to summarize the seasonal nature of the readings for this particular room. The data smooth was generated by the S-plus routine, lowess, which implements the smoothing procedure described by Cleveland (1979). (A copy of the data was

Table 2: Relative humidity and temperature summary

Location	Relative Humidity			Temperature		
	# of Readings	% below 45%	% above 65%	# of Readings	%below 68°F	% above 72°F
Boyd Gallery	149	36.9%	6.0%	153	24.8%	44.4%
Bowdoin Gallery	149	35.6%	6.0%	153	32.7%	43.1%
Rotunda	148	39.2%	8.1%	152	23.7%	42.8%
Walker Gallery	149	41.6%	7.4%	153	19.6%	45.8%
Halford Gallery	146	41.8%	9.6%	150	7.3%	54.7%
Becker Gallery	139	41.7%	3.6%	143	9.1%	44.8%
Art Preparation Room	139	38.8%	7.2%	143	7.7%	58.0%
20th Century Gallery	138	46.4%	6.5%	142	3.5%	53.5%
Homer Gallery	139	45.3%	7.9%	143	11.2%	42.0%
Temporary Exhibition G.	148	47.3%	12.2%	152	7.9%	46.1%
Object Storage	137	13.1%	19.0%	138	53.6%	29.0%
Paintings Storage	135	48.1%	8.9%	136	10.3%	41.2%
Publications Storage	137	33.6%	11.7%	141	43.3%	25.5%
Outside	107	17.8%	37.4%	117	65.8%	20.5%

added at the beginning and end of the year to stabilize the smooth.) From the plots it is clear that the hot humid days in summer lead to relative humidities and temperatures that exceed the upper target limit while the cold, dry days in winter give readings below the lower limit.

The residuals from the data smooth reflect both the magnitude of the day to day variations and measurement error in relative humidity and temperature. These are shown in Figure 2 with reference lines indicating the target tolerance ±10% in relative humidity and ±2°F in temperature. These plots suggest that the day to day variation in the Bowdoin Gallery is such that relative humidity and temperature would be in the target range most of the time if the seasonal component could be controlled. The same is true for other locations in the museum.

3.2 Comparison of locations

Different locations in the museum can most easily be compared by superimposing their data smooths as shown in Figure 3.

It appears that there is some variation throughout the museum in both relative humidity and temperature. Grouping these profiles by the location of the rooms

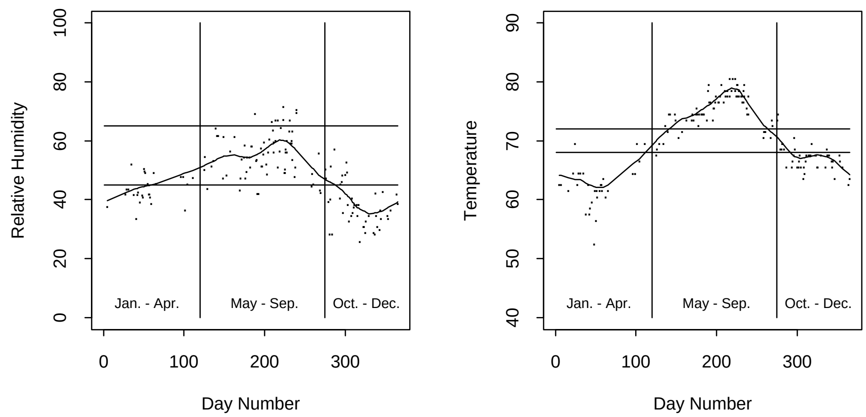

Figure 1: Relative humidity (%) and temperature profiles (°F) for the Bowdoin Gallery. The horizontal lines indicate the target limits of 45% to 65% for relative humidity and 68°F to 72°F for temperature. The vertical lines mark the approximate end and beginning of the heating season.

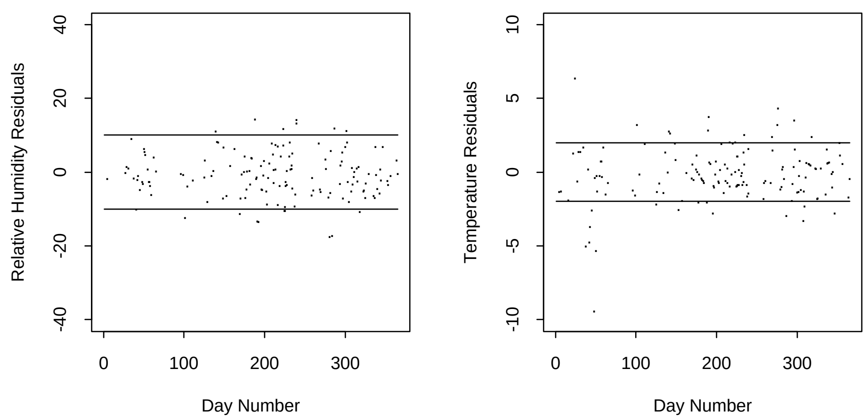

Figure 2: Relative humidity (%) and temperature (°F) residuals for the Bowdoin Gallery. The horizontal lines indicate the target tolerance of ±10% in relative humidity and ±2°F in temperature.

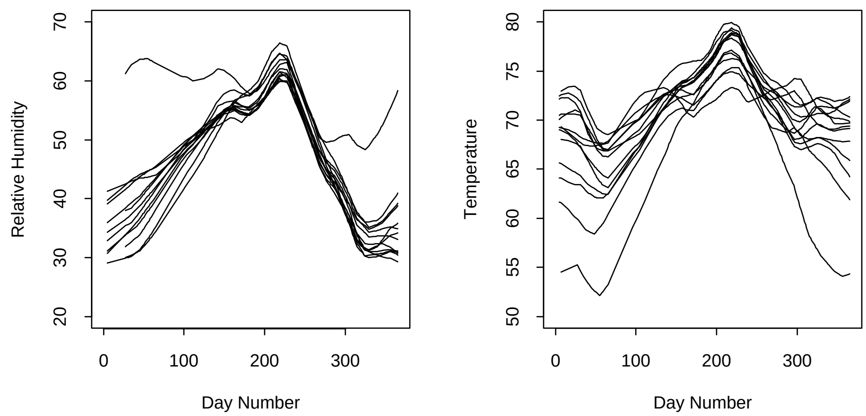

Figure 3: Superimposed data smooths of relative humidity (%) and temperature (°F) for all locations.

in the museum, we discovered that the three upstairs galleries and the rotunda have very similar curves, as do most of the galleries downstairs. In fact, only the Temporary Exhibition Gallery and storage areas appear to be significantly different from the other rooms downstairs (see Figures 4 and 5).

The differences throughout the museum can be characterized by the extremes in the relative humidity and temperature. The further one goes downstairs, the more extreme the relative humidity becomes, and the less extreme the temperature. That is, the upstairs rooms have temperatures that are slightly higher in summer and lower in winter than the downstairs rooms. And the (lower) downstairs rooms have relative humidities that are slightly higher in summer and lower in winter than the rooms upstairs. Object Storage, which is unheated, and to a lesser extent, Publications Storage differ from the rest of the museum particularly during the winter months when they exhibit very cool temperatures.

Museum artifacts and people respond to the temperature and relative humidity. However, relative humidity is a function of the temperature and the amount of moisture in the air. If air with a given moisture content is moved to a location with a higher temperature, the relative humidity decreases. This is the reason that the air in our houses becomes dry in winter as cold air from outside is heated to a comfortable room temperature. Similarly, as air with a given moisture content is moved to a location with a lower temperature, its relative humidity increases. At some critical temperature, called the dewpoint, the relative humidity reaches 100% and the moisture in the air condenses.

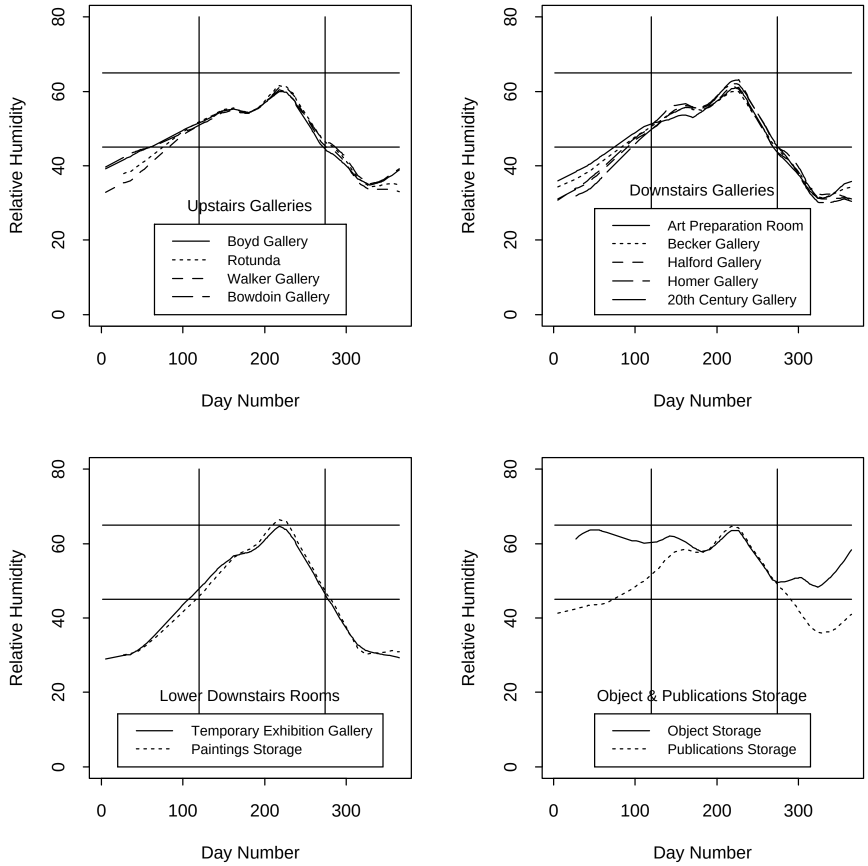

Figure 4: Relative humidity (%) data smooths by location. The horizontal lines indicate the target limits of 45% and 65% for relative humidity. The vertical lines mark the approximate end and beginning of the heating season.

The key to understanding the differences in relative humidity found throughout the museum is a specific humidity. The specific humidity calculated here is the ratio of the mass of water (in grams) to the mass of dry air containing that water (in kilograms). In contrast to relative humidity, specific humidity does not change with temperature. The data smooths for specific humidity, shown superimposed for every location in Figure 6, suggest that the amount of moisture in the air is very similar throughout the museum.

The fact that the specific humidity is essentially the same at all locations at a given time indicates that the moisture content in the museum is largely determined by air exchange. This means that at any particular time, any differences in relative humidity in different areas of the museum are a direct consequence of

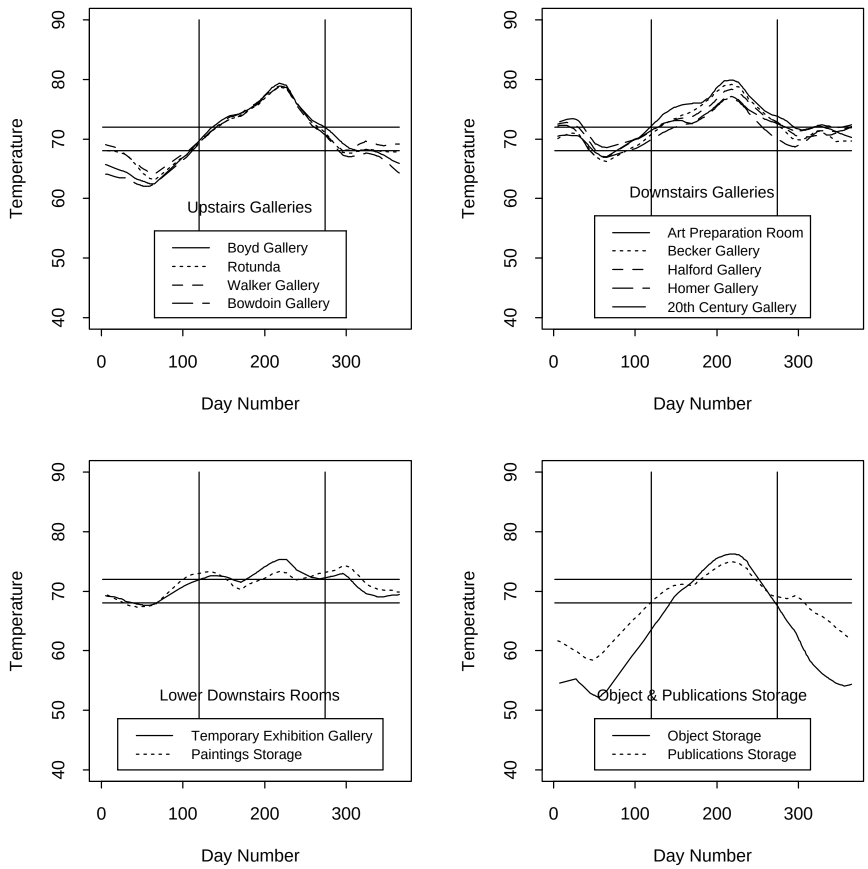

Figure 5: Temperature (°F) data smooths by location. The horizontal lines indicate the target limits of 68°F to 72°F for temperature. The vertical lines mark the approximate end and beginning of the heating season.

differences in temperature. Since the air inside the museum is constantly being replaced by the air from outside, the specific humidity inside the museum, and the resulting conditions throughout the museum, will reflect the outdoor conditions.

3.3 Relationship with outside

As the outside air enters the museum, one would expect the specific humidity inside to become the same as that outside. There will, of course, be some time delay, so that the highest correlation between the inside and outside specific humidity values will occur after some characteristic time lag. Since the air exchange rate in buildings is typically several hours, our daily data could not be used to

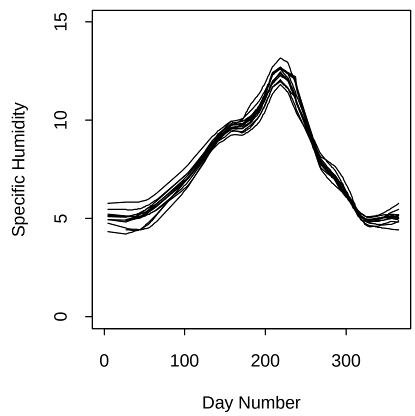

Figure 6: Superimposed data smooths of specific humidity (g/kg) for all locations.

estimate the time lag.

To estimate the time lag, a new monitor was installed in the Bowdoin Gallery. During a 5 day period in November, a series of relative humidity and temperature readings was collected at 5 minute intervals both inside and outside. These readings were averaged to give specific humidity values for the Bowdoin Gallery and outside at two hour intervals. The correlation between the inside and outside specific humidity values for various lag times (in hours) is shown in Figure 7. From this we conclude that it takes about 6 to 8 hours for the moisture content of the outside air to infiltrate the museum environment.

The 6 to 8 hour time lag is in the range expected for the air exchange rate and amount of outside air introduced. Although is it based on data for only a few days in November, it seems likely that there is a similar relationship between the specific humidities inside and outside throughout the year. This is supported to some extent by the sling psychrometer data for which the time lag was found to be less than one day. Also, the specific humidity profiles for the Bowdoin Gallery and Outside, shown in Figure 8, are very similar, the only noticeable difference occurring during the winter months when the values in the Bowdoin Gallery seem slightly higher.

4. Discussion

The analyses above suggest the following interpretation of the low and high relative humidity values observed in the museum during the winter and summer months, respectively. The low relative humidity values probably result from the inherently low specific humidity and temperature in the outside air during the

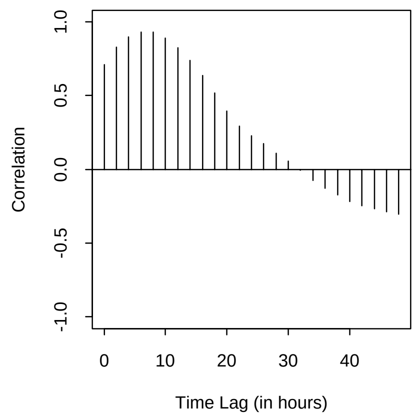

Figure 7: Correlation of inside and outside specific humidity values for various lag times in hours.

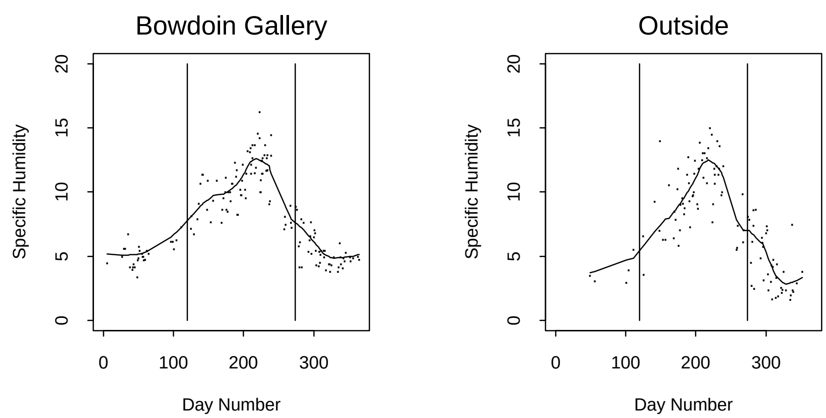

Figure 8: Specific humidity (g/kg) inside and outside. The vertical lines mark the approximate end and beginning of the heating season.

winter months. Clearly some moisture is being added to the museum air in the winter, since the specific humidity in the Bowdoin Gallery is higher than that outside. However, insufficient moisture is being added to maintain the target humidity levels in the winter months. During November, when neither the temperature nor specific humidity outside were particularly low, the relative humidity in the Bowdoin Gallery hovered about the lower tolerable limit. When both the temperature and specific humidity outside are lower in the winter months, we should expect the relative humidity inside to be even lower.

During the summer, when the heat in the museum is not regulated, the high

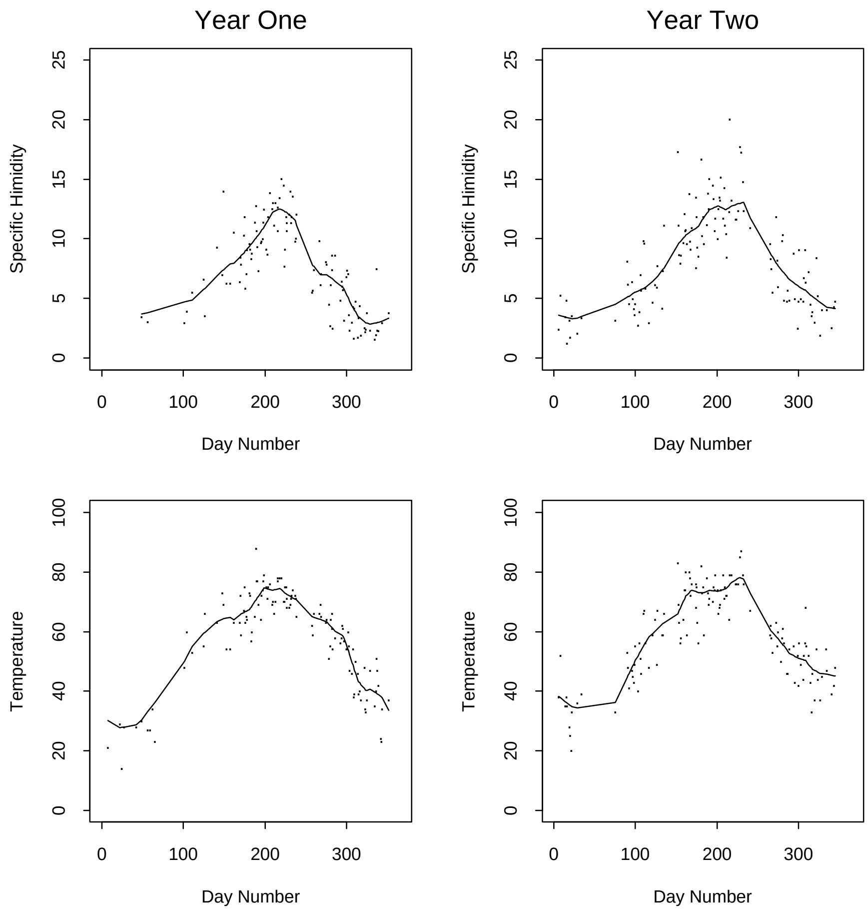

Figure 9: Outside specific humidity (g/kg) and temperature (°F) for years one and two.

relative humidity values in the museum reflect high outside specific humidities. The situation may be aggravated by museum temperatures that are somewhat lower than those outside. Comparison of the relative and specific humidity values in years one and two supports this conclusion. In year two, there was more hot humid weather and a correspondingly higher incidence of days with high relative humidity in the museum (see Figure 9).

5. Consequences for the College

Based on our analyses, it was clear the Walker Art Building needed to have a climate control system installed. Such systems are expensive. The College recognized this need and its importance by including a climate control system for the museum as a part of its next capital campaign. In preparation for this new system, several improvements have been made to the building envelope. The skylights in the upstairs galleries were replaced with insulated units, the terra-cotta dome was structurally restored and re-covered with copper, and new roofing was installed. During the interim, additional pressing renovations have been identified that have postponed the installation of a climate control system in the Walker Art Building. Thus a decade later, the College is still without the necessary means to adequately protect its art collection. This is not negligence but the reality for a small college where there are multiple needs competing for limited financial resources.

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