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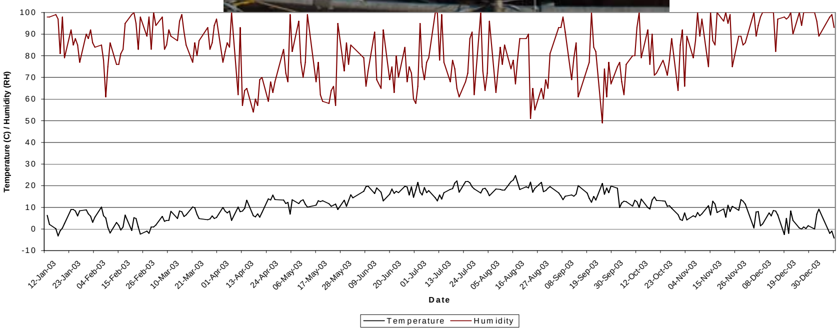
The Monitoring of Environmental Conditions within Corporate Collections at Keyworth and Murchison House: 2005

Information Management Programme

Internal Report IR/06/010



BRITISH GEOLOGICAL SURVEY

INTERNAL REPORT IR/06/010

The Monitoring of Environmental Conditions within Corporate Collections at Keyworth and Murchison House: 2005

Paul Shepherd, Graham J. Tulloch.

Key words

Environment, Temperature, Humidity, Monologger, Thermohygrograph, Microtherm, Stevenson Screen, Core Store, Materials, Specimens

Front cover

Graph detailing weather readings at Keyworth & photograph of Murchison House 'weather station'.

(Photograph by G J Tulloch)

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Foreword

This report third in the series of the ongoing study by the British Geological Survey (BGS) into the environmental conditions of certain storerooms under the control of the Corporate Collections Management Project at both the Keyworth and Edinburgh sites.

Acknowledgements

The authors would like to thank those whose assistance in the delivery of the data over the period of reporting has made their task easier.

Paul would like to thank the following people:

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Louise Neep for photographing the 2005 hygrograph plots.

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I would also like to thank Ken Lawrie and Keith Holmes for their assistance with MS Access in presenting the half-hourly summed rainfall data. Thank you all.

Photograph credits:

Plate 1	Louise Neep
Cover photograph	Graham Tulloch

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Summary

This report presents the environment data gathered during the calendar year 2005 in the storerooms for the British Geological Survey's Corporate Collections Archives.

The report follows the pattern laid down in the first of the series, released in 2004, *The Monitoring of Environmental Conditions within Corporate Collections at Keyworth and Murchison House 2002-03*, with comparisons made between data collected in pervious years to assess the benefits or otherwise of modifications to either working practices or the fabric of the building.

1 Introduction into Environmental Monitoring

Monitoring the environment in sample stores is vital to the long-term strategy of the Corporate Collections Management Project. Recording fluctuations in the temperature and humidity within the store areas will, hopefully, pre-empt any potential problems with sample deterioration.

Standards in the Museum Care of Geological Collections, 1993 details the parameters in which rock & fossil material should be stored. Conditions outside these parameters or large variations within them can cause the acceleration of sample degradation, pyrite decay and efflorescence for example.

Without continual monitoring the environment of sample stores and therefore the possible threat to the samples cannot be accurately known.

As the conditions within stores was discussed in the report *The Monitoring of Environmental Conditions within Corporate Collections at Keyworth and Murchison House 2002-03* together with the strategy, equipment and the rationale behind the positioning of the various monitors and logging equipment it is not our intention to restate these in this volume unless there is an alteration to one of these factors.

1.1 AIMS AND OBJECTIVES

Strategy for Keyworth and Murchison House

- To routinely monitor the temperature and relative humidity in all storage areas of the collections and, where possible, monitor the external climatic variations, to determine what affect this has on any climatic variations within the Collections.
- Interrogate data and report to the appropriate authorities any adverse readings, which may indicate a defect in the building, e.g. structural, heating or ventilation, to allow action to be taken to prevent any damage or further damage to the collections.
- Use our knowledge of the internal climates to store the collections in the most suitable locations, where possible.
- To randomly monitor temperature and humidity readings in individual storage containers within the collections to determine if a buffering effect, from variations in the main storage areas, takes place.
- Recommendations and improvements should be made as required, based on the data collected, in order to preserve the collections for future generations.

A summary detailing the Strategy for Environmental Control can be found in Appendix 1.

1.2 ENVIRONMENTAL CONDITIONS WITHIN MUSEUMS

Any geological collection or any other type of collection, however small it is, that has a significant importance to an institution or the public, should be carefully maintained and preserved.

One of the most important factors is to monitor and control the environmental conditions within the collections.

Numerous geological materials are sensitive to certain components of the environment, which include relative humidity (RH), temperature, atmospheric chemicals, light and vibration. Brunton *et al* (1985).

The main environmental conditions to affect any collection are temperature and relative humidity. Variations in temperature are associated with its relative humidity. As a volume of air is cooled, it becomes more saturated, and less saturated as it is heated. Therefore any major changes in temperature especially rapid fluctuations should be avoided. Temperatures below 10°C should also be avoided because of high humidity values and the risk of condensation. The ambient storage temperature for geological specimens should be between 16-22°C. Doughty *et al* (1993).

Any geological collection can be potentially damaged or destroyed by relative humidity and are therefore sensitive to changes in humidity in the environment in which it they are stored. High humidity levels can lead to deliquescence, chemical change such as pyrite decay, and deformation of some materials through the absorption of moisture. Extremely low humidity levels can cause efflorescence and shrinkage of some moisture absorbent specimens, including shale and sub-fossil bone. For general geological materials the ambient relative humidity should be around 45-55%. *Child* (1994).

In addition to maintaining acceptable conditions for the general collections, some geological specimens require storage under different conditions; these are specified in Table 1. For storage of non-geological specimens, such as documents on paper, these recommended conditions are shown in Table 2. Where storage conditions are required outside of these limits, conditioned microclimates must be used.

Material Type	**Ambient Temperature**	**Ambient Relative Humidity**
General Conditions	16-22°C	45-55%
Cold Store		
Fresh borehole material in a barrier film	4°C (+/-2°C)	n/a
Sensitive material		
Pyrites & Marcasite (and fossils containing these minerals)	16-22°C	< 55%
Fossils with shale or clay matrix	16-22°C	Not Below 40%
Sub-fossil bone, tusks, teeth (*Child*, 1994)	18-22°C	50-55%

Table 1: Ambient Storage Conditions for Geological Specimens (Doughty & Brunton, 1993 & Child, 1994)

Material Type	Ambient Temperature	Ambient Relative Humidity
Historical Records		
Documents on Paper - frequently used material	16-19°C	45-60%
infrequently used material	13-16°C	45-60%
Modern Records		
Magnetic recording media	Stored in an environment as close to that in which it will be consulted	

Table 2: Ambient Storage Conditions for non-Geological Specimens (BS 5454:2000)

1.3 AREAS OF INVESTIGATION

The monitoring for this report has been undertaken at two sites within the British Geological Survey (BGS). These are located at Keyworth, Nottingham, and Murchison House in Edinburgh.

1.3.1 Keyworth

The areas of investigation for this report include the Palaeontology Collections, Core Store (including the Petrology and Borehole Collection), together with the NGRC and now the Keyworth Library. In addition to this, meteorological readings from the BGS Keyworth weather station are also used for comparative purposes between external and internal environments.

The Keyworth site houses numerous types of collections that come under the category of Corporate Collections.

This includes the Borehole Collection, which contains over 3000 pallets of core from England & Wales, from 3000 boreholes. Together with over 600,000 registered samples from onshore UK boreholes and 1,500,000 cutting samples from 1,500 onshore UK oil wells.

The Palaeontological collection includes about a quarter of a million macro-palaeontological specimens of museum quality. Together with an additional two million specimens collected during mapping projects, which are still are of significant importance. This makes this one of the most important single collections of British fossils in the world.

The Petrological collection contains more than 200,000 specimens, which is used for reference purposes. This collection is made up of a suite of smaller collections, which includes England & Wales sliced rocks, reference minerals, museum reserve collection, building stones and private collections. *Hollyer et al* (2000).

The NGRC (National Geological Records Centre) is a unique archive of national importance containing over three million items with information dating back over 200 years. Since its inception, the National Geological Records Centre has maintained, collated, and indexed large collections of geological data. The Data Centre is a recognised Place of Deposit for Public Records and is also the Natural Environment Research Council's Designated Data Centre for data generated by research in earth sciences. *Bowie* (2000).

The BGS Library at Keyworth, holds reference literature and documents to support bibliographical services both to staff (at home and overseas) and to members of the public. In over 150 years of existence, the collections have grown to become one of the world's major earth science libraries. Material is acquired by exchange as well as by purchase and in the past has been enhanced by incorporation of other collections, such as the extensive holdings of the former Overseas Geological Surveys which merged with the home survey in 1965.

The Library collections comprise the following types of material:

- photographic albums and prints (some 70 000 photographs in total)
- World Maps Register Index (map registers for the library's holdings for overseas areas)
- books, monographs, conference volumes (over 500 000 items)
- serials (some 3000 periodical titles currently taken)
- pamphlets, scientific papers, standards, theses
- archives of historical and national interest *BGS* (2004)

1.3.2 Murchison House

This report relates to the Collections areas reported on in previous years, namely the Palaeontology and Mineral and Petrography stores in Murchison House. In addition to these stores a new Archive Room has been added to the routine monitoring programme.

The Palaeontological collection comprises approximately half a million specimens in 3 main sub-collections from Scotland and northern England: the working, or Survey Collection, the Museum, or Type and Stratigraphical Collection and the Palaeontological Slide Collection.

The Collections are housed in linked but separate stores in a variety of trays ranging from museum standard cabinets to lidded and open wooden and plastic trays.

The Petrological collection contains more than 130,000 specimens. As with the Palaeontological collection this collection comprises a number of sub-collections, including the Scottish sliced rocks, S&N, the Murchison, the Edinburgh and the Systematic collections. All of these collections with the exception of the Edinburgh & Systematic collections have associated thin sections. There are also a small number of reference minerals, and a growing number of building stones samples. *Hollyer et al.* (2000). This collection is stored in two rooms, one containing cabinets for the thin section collection and one housing the remaining sub-collections.

These important Collections, both Palaeontological & Petrological, assist Survey field geologists in mapping projects and an increasing number of commercial activities; additionally external academic and commercial enquirers utilise the Collections in their studies. It is, therefore, important that the storage environment is as stable as possible in order that the integrity of the Collections is preserved.

The Archive Room contains archive data for permanent retention: contents include field maps and notebooks generated by BGS staff in the course of their work surveying the UK landmass. There are also BGS seismic data and offshore reports, mine abandonment plans and other donations from sources outwith the Survey. These records must be stored in conditions laid down in BS5454:2000.

Data from an external logger is also available, this provides a useful comparative dataset to those data acquired inside.

1.4 ENVIRONMENTAL MONITORS

Between Murchison House and Keyworth two different types of monitors are used to measure the temperature and humidity of the collections; a further two monitors measure external climatic variations.

The main logger is a combined temperature and humidity recorder, the Digitron Monolog2. This instrument records data at an operator set interval and is downloaded regularly to provide a complete record of the environment of an area.

The other instrument used is a Thermohygrograph.

2 Monitoring at Keyworth

At Keyworth, readings from sixteen monitors have been used to produce this report. In addition to the permanent monitors used during 2004, a new monitor was placed in a mahogany cabinet drawer on the first floor of the museum during the 6th May 2005. On the 1st March 2005, a new monitor was placed in the weather station, to provide more frequent external readings.

New localities for this report include a new monitor within a museum cabinet and one within the weather station.

It must be noted that the Core Store Thermohygrograph mechanism stopped working around the 4th July 2005. It was decided not to replace this device, as there was a sufficient number of monologgers already in the Core Store, with the closest being in the Pallet Store.

2.1 CALIBRATION DATA

All environmental monitors used at Keyworth have been initially calibrated at different times. It was decided in order for the data to be consistent, that they all should be re-calibrated at the same time. Sending the loggers back to the manufacturers for re-calibration would be too costly and so it was decided that they should be calibrated 'in house'.

2.1.1 Calibration Method

Over the period 5th May to 6th May 2005, all of the monologs and both Thermohygrographs were placed within an empty mahogany, glass fronted wall cabinet within the museum. This location was chosen, as it was large enough to house all of these monitors, including some additional monitors that required calibrating for other staff members.

The advantage of using this location was that any fluctuations occurring in the museum would not be recorded within the cabinet, due to the excellent buffering properties of the mahogany wood and their glass fronts.

The raw data collected during the calibration period was downloaded from the monologs, whilst the data from the Thermohygrographs was manually extracted. These were then tabulated into excel and graphed. (See Figure 1)

The layout of the graph is as follows; the temperature readings are recorded towards the bottom of the vertical axis with the ideal temperature ranges of 16-22°C indicated by solid black horizontal lines. The humidity readings are positioned above the temperature values; the ideal humidity ranges of 45-55% indicated in the same manner as the temperature. This layout applies to all the line graphs within this report.

Over this calibration period the temperature variation is marginal, except for both thermohygrographs, which are showing lower values; even though all the monitors are within the acceptable ranges.

For the humidity readings, all of the monitors are below the minimum recommended range, except for the museum hygrograph and Core Store extension monitors. These are showing readings within the acceptable parameters. All of the values are constant during this calibration period.

This graph and associated data was then used to calibrate the loggers so that the values were more consistent with each other.

Using the four newest monitors, which should be the most accurate; the calibration factor was based on data from these, to provide a benchmark. Average temperature and humidity readings were obtained from these monitors over the calibration period and then applied to the remaining older monitors. This method should give us true values for all the locations without returning the monitors to the manufacturer for re-calibration. Table 3 summaries the calibration values.

Logger No	Logger Name	Av. Temperature	Adjustment	Av. Humidity	Adjustment
0112-096	Core Store Main Corridor	19.9	+0.1 C	38	+3.7%
0109-595	Core Store Extension	19.5	+0.5 C	47.1	-5.4%
0109-597	Pallet Store	19.8	+0.2 C	40.6	+1.1%
0112-066	Tray Store	20	Nil	39.1	+2.6 %
n/a	Museum Hygrograph	17.7	+2.3 C	47.5	-5.8%
n/a	Core Store Hygrograph	18	+2.0 C	45.1	-3.4%
0407-204	Cold Store	19.9	+0.1 C	44.5	-2.8 %
0407-196	NGRC Box G239	19.9	+0.1 C	40.1	+1.6%
0407-217	NGRC Aisle 67	20	Nil	40.3	+1.4%
0407-219	NGRC Strong Room	20	Nil	41.6	+0.1 %
0407-210	Museum 1st Floor	19.8	+0.2 C	39.4	+2.3%
0407-213	Museum Ground Floor	19.9	+0.1 C	42.6	-0.9 %
Average calibration temperature & humidity based on the 4 newest new monitors during calibration period					
0429-015	Conservation Laboratory				
0429-018	Weather Station				
0429-033	Library Strong Room	20		41.7	
0429-037	Museum Cabinet				

Table 3: Summary of Calibration Data – Keyworth

The data for this calibration period was automatically adjusted using a macro in Microsoft Excel. This newly ‘amended’ data was then re-graphed to show all of the monitors after the calibration factor had been applied. (See Figure 2). This now shows that all of the monitors for both temperature and humidity are calibrated together with little or no variations between them.

All Loggers prior to Calibration - Keyworth 2005

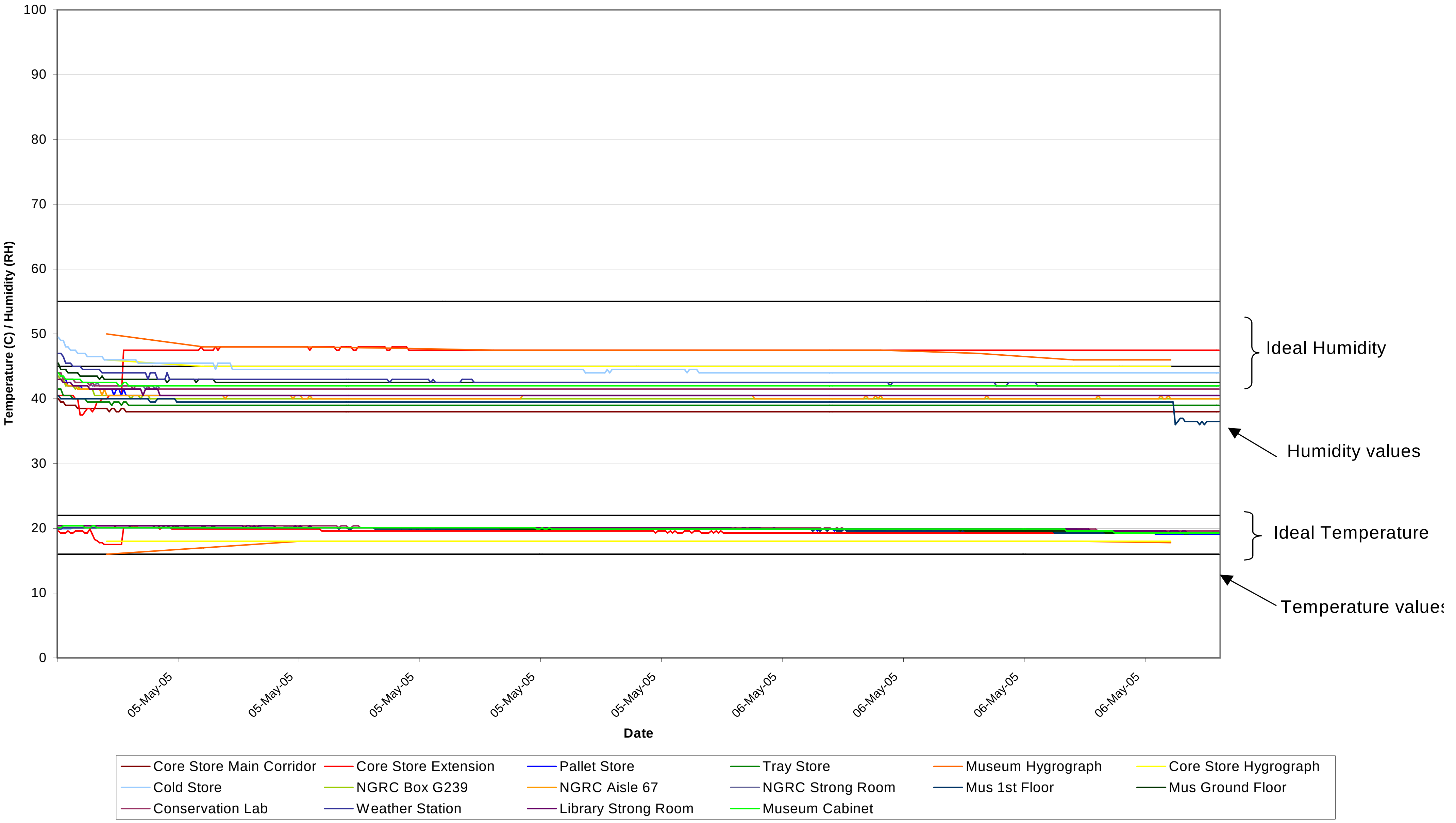

Figure 1: All Loggers prior to Calibration Period - Keyworth 2005

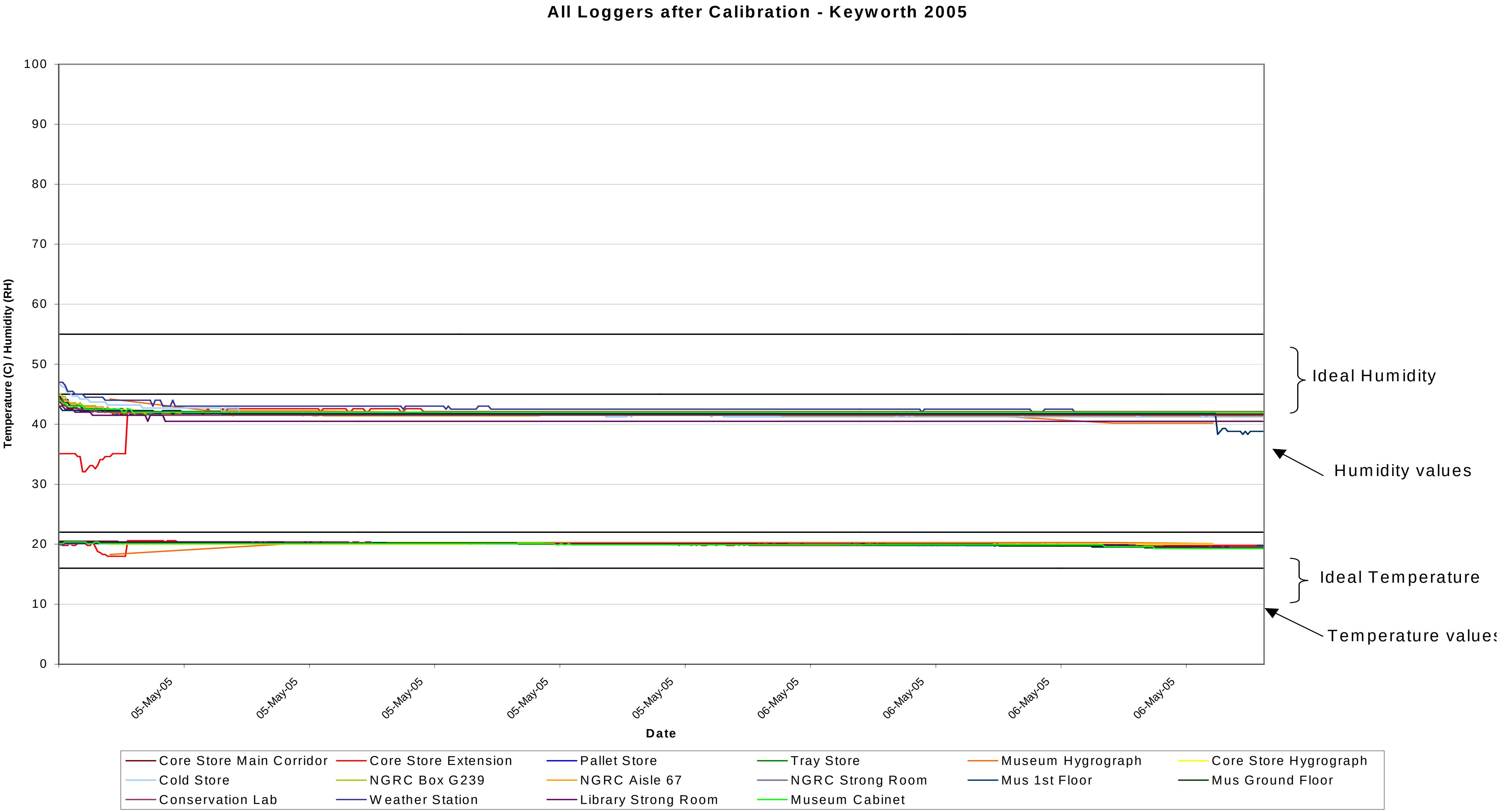

Figure 2: All Loggers after Calibration Period - Keyworth 2005

2.1.2 Calibration Summary

From the calibration period this year, variations in temperature and humidity were seen to still exist between the monitors, especially ones of the same types, even though they were situated in the same location. The adjustments made this year were small, and these alterations are comparable to those made to the data used for last years report.

This indicates why the environmental monitors should be calibrated on a regular basis. This then allows us to obtain a more accurate understanding of the climatic changes within the storage areas. More accurate comparisons can then be made between different storage areas in the same time period.

The 'in-house' calibration method used at Keyworth whilst not being as accurate as re-calibrations carried out by the manufacturer, was felt to be justified as the savings made by in-house calibration could be used to purchase additional monitors and thus we could monitor additional areas within the collections.

2.2 DATA EXTRACTION

The data for this report was downloaded from the monologgers in their original format and saved in the form of .lcf files. This file extension is used to view the data with the relevant loggers software. This data was then converted into a .csv file format to enable the import into Microsoft Excel. Visual extracted readings from the Thermohygrographs and weather readings from the weather station were entered directly into Excel.

The raw data from the monologgers was downloaded into a GMT format via a laptop computer.

All the data was calibrated where necessary, using a calibration macro in Excel. From this the data was filtered using Excel to show readings to the nearest 30 minutes or in the case of the hygrographs, every two hours and every 24 hours for the weather station.

This data was then used to generate the graphs in Excel.

Please note: all data for this report can be found on a compact disk attached to this report.

The layout of the data will be in the following format:

- All raw unformatted data (lcf format) will be presented in folders for each type of monitor. Raw data will be presented in a .csv format (readable by MS Excel).
- Data used for calibration purposes will be in a sub folder.
- The thirty minute extracted, calibrated data used for yearly graphs, will be presented in folders. The yearly histogram data is also included.

2.3 YEARLY CALIBRATED RESULTS 2005

The main objective for Keyworth is to routinely monitor temperature and humidity, within the storage areas of the collections. This has now been ongoing for the last four years.

Three monologgers are situated within the Core Store, they are located within the pallet store, core store extension and tray store. The pallet store logger is positioned in the second aisle, about a third of the way down, two metres above the ground.

Within the core store extension, a logger has been placed 4.5 metres from the end of the first fully filled rack.

Whilst within the tray store a logger is positioned on the top floor, 77cms above that floor level and adjacent to the main open area of the core store, which is approximately 7.5 metres below.

Each of these monologgers are recording data at three-minute intervals.

Thermohygrographs are located in the main area of the core store at ground level and on the ground floor of the museum respectively. It must be noted that the Core Store Thermohygrograph mechanism stopped working around the 4th July 2005. It was decided not to replace this device, as there was a sufficient number of monologgers already in the Core Store, with the closest being in the Pallet Store.

A monologger has been positioned on the first floor of the museum, on a workbench towards the rear of the museum, away from any exits that may affect the readings.

During March 2005, a monologger was placed within the weather station. This would provide additional readings at regular intervals, rather than once every 24 hours and thus give a more accurate comparison between external and internal environments. As the monologger did not start recording data until March, both the thermometer and monolog data are showing side-by-side in Figure 3. To simplify the data, averages over the year, for both types of monitors are shown. It can be seen that the temperature values are consistent between the thermometer and monologger. The humidity readings follow a similar trend, even though values are higher with one monitor than the other, except on two occasions in August & September, where readings appear to contradict this. Elevated readings between monitor types could be due to variations of the wicking capabilities for each monitor at high humidity levels.

This chapter (2.3) will discuss the results for 2005 and will also make comparisons with the annual readings from 2004. Monitors positioned in new locations will be presented and discussed in subsequent chapters, as it was decided that the graphs would be too complex to discuss the data properly.

2.3.1 Yearly Calibrated Results Discussion

An annual graph for 2005 has been produced for all the main loggers used in 2005, (Figure 4) with corresponding acetate overlay displaying external climate conditions for that year (Figure 3). These graphs show the trends throughout the year plus any changes in temperature and relative humidity.

The results from Figure 4 show that there are major fluctuations in humidity readings for all of the monitors, even though they all follow a similar pattern throughout the year, with values recorded both above and below the general recommended 45 – 55% parameter. A migratory pattern is also present for the temperature readings, which changes less often through the 16 –22 C range over the year.

From January through to mid March there is a noticeable decrease in humidity readings to below the 45% benchmark recommended for this type of material. The monitors in the museum show higher readings compared to the other locations. This also shows this to be the only location were the humidity reaches the 45-55% guidelines. This however is only for 17% of the time. These low humidity values could have been caused by both extended periods of cold weather, which have reduced the internal humidity, and the use of central heating, which dries out the air inside.

Through the rest of March to mid May, there is a slight improvement in the humidity values for all areas towards the recommended parameters. Both sensors within the museum still show elevated values compared to the other locations, especially during mid March, where there is a noticeable rise towards the 45-55% guidelines.

From mid May through the summer until early November, all of the areas being monitored show an improvement in their humidity. On average all areas are within the recommended 45-55% range for at least 55% of the time, except for the museum, which accounts for 33%. During this period, the museum hygrograph and the museum 1st floor monitor is showing the higher readings, whilst the Core Store extension is recording lower values. There are two periods (15-20 June, and end of July), where all the monitors show unusually high humidity readings. A possible factor could be due to two periods of high external temperatures and humidity experienced around these times.

Through November to the end of December, all of the areas monitored show a drop in humidity levels, especially around middle of November. Towards the end of November, this decline stabilizes to an average of 30% RH. When comparing this to the rest of the year, the first floor of the museum is now showing the lowest humidity levels, whilst the core store extension, which had the lowest values, is now recording average values. The pallet store and tray store are now showing the higher values.

Temperature readings taken from January until mid March often appear within the 16-22C recommended guidelines for general storage. Large areas of the core store (excluding the tray store) are on average 99% of the time within range. Compared to 67% of the time for all the other areas. The lowest readings are recorded on the museum 1st floor monitor, whilst the highest is from the monitor placed within the tray store.

A similar pattern can be seen from mid March until the middle of May, where all areas show readings within 16-22C ranges on a more regular basis, this accounts for 81-98% of that period. The exception to this being the tray store that only accounts to 60% of that time. Throughout summer and into late autumn, all of the areas being monitored are displaying readings within the acceptable parameters. There are two main occurrences, around the 20 June and 15 July where all the monitors show an increase in temperature, with the tray store monitor reaching 26C. This is probably due to the close proximity of the monitor in relation to the metal roof of the core store, which is heating the air directly below it; compared to the other monitors, which are positioned closer to the ground. This is apparent during the rest of the summer, where rises in temperature are more noticeable within the tray store, compared to the museum. The museum building is of different construction and is therefore not affected in the same way during the hotter summer months. From mid autumn to the end of 2005, all areas fall within the recommended 16-22C range. There are occasions when the core store extension readings fall below 16C. This coincides with the shutter doors at the rear of the core store being left open for some time, to take delivery of material from Penzance. Additionally it can be seen that museum readings are higher than the other areas. This is probably due to the maintenance work carried out on central heating system to reduce the high temperatures of 27C within the museum stairwell.

If the acetate for the external temperature and humidity, Figure 3, is placed over Figure 4 comparisons can be made between the internal and external environments. From looking at both graphs, it can be seen that the external temperature is having an effect on the temperatures recorded internally across all monitored locations. At the beginning of March, there is a rise in external temperature, which appears to cause the internal temperature to increase; this is especially noticeable for all the core store locations. A similar pattern can be seen during June, July and the end of August, when the highest annual temperatures were recorded. This is reflected in an increase in internal temperatures. Once the external temperatures begin to fall, this allows the internal temperatures to return to normal. This influence on internal temperatures is not seen during the winter and spring months, even though colder temperatures are recorded. This is because the central heating across the site will be in operation, keeping temperatures more stable and acting as a buffer to the influence of external temperature.

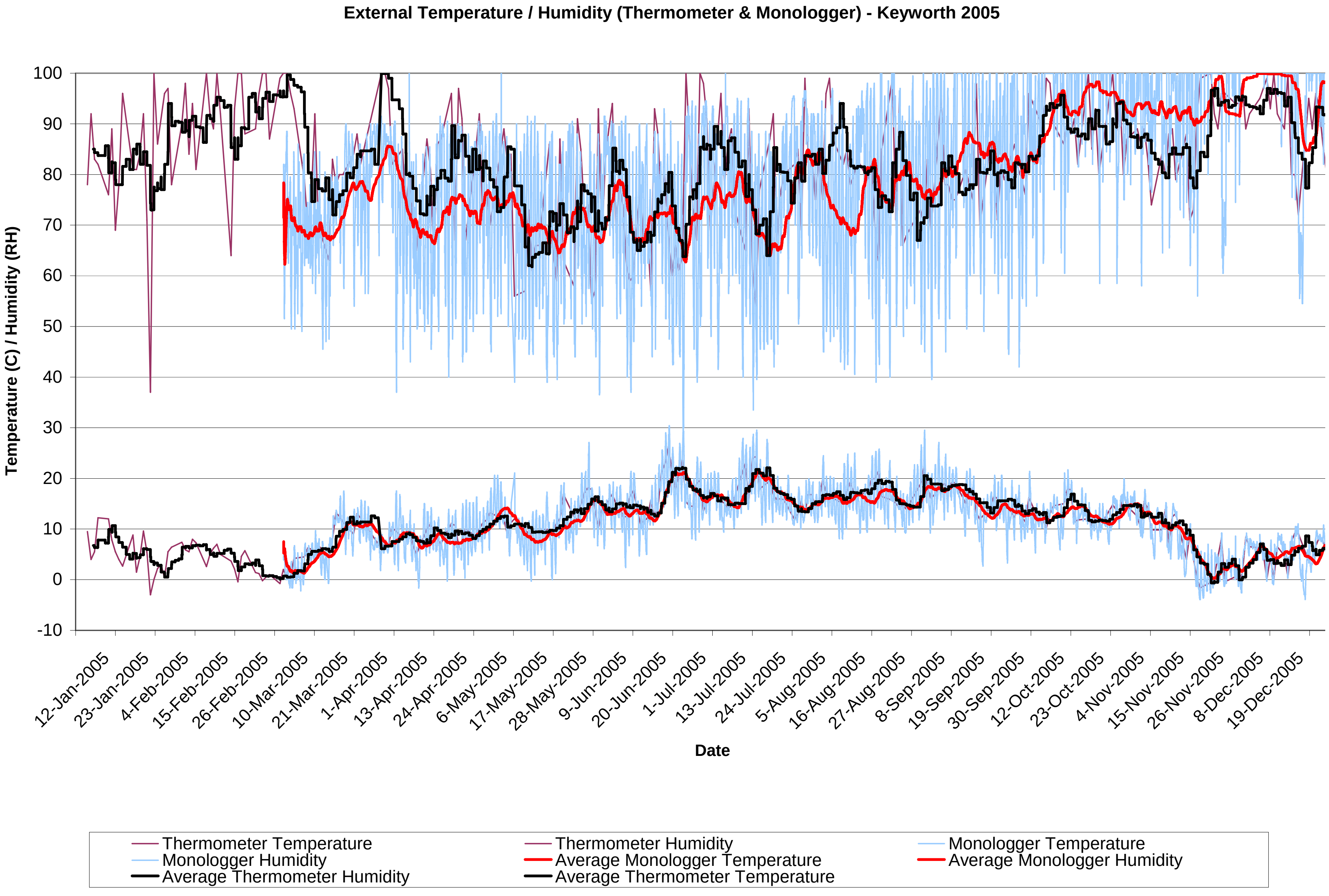

Figure 3: External Temperature / Humidity - Keyworth 2005

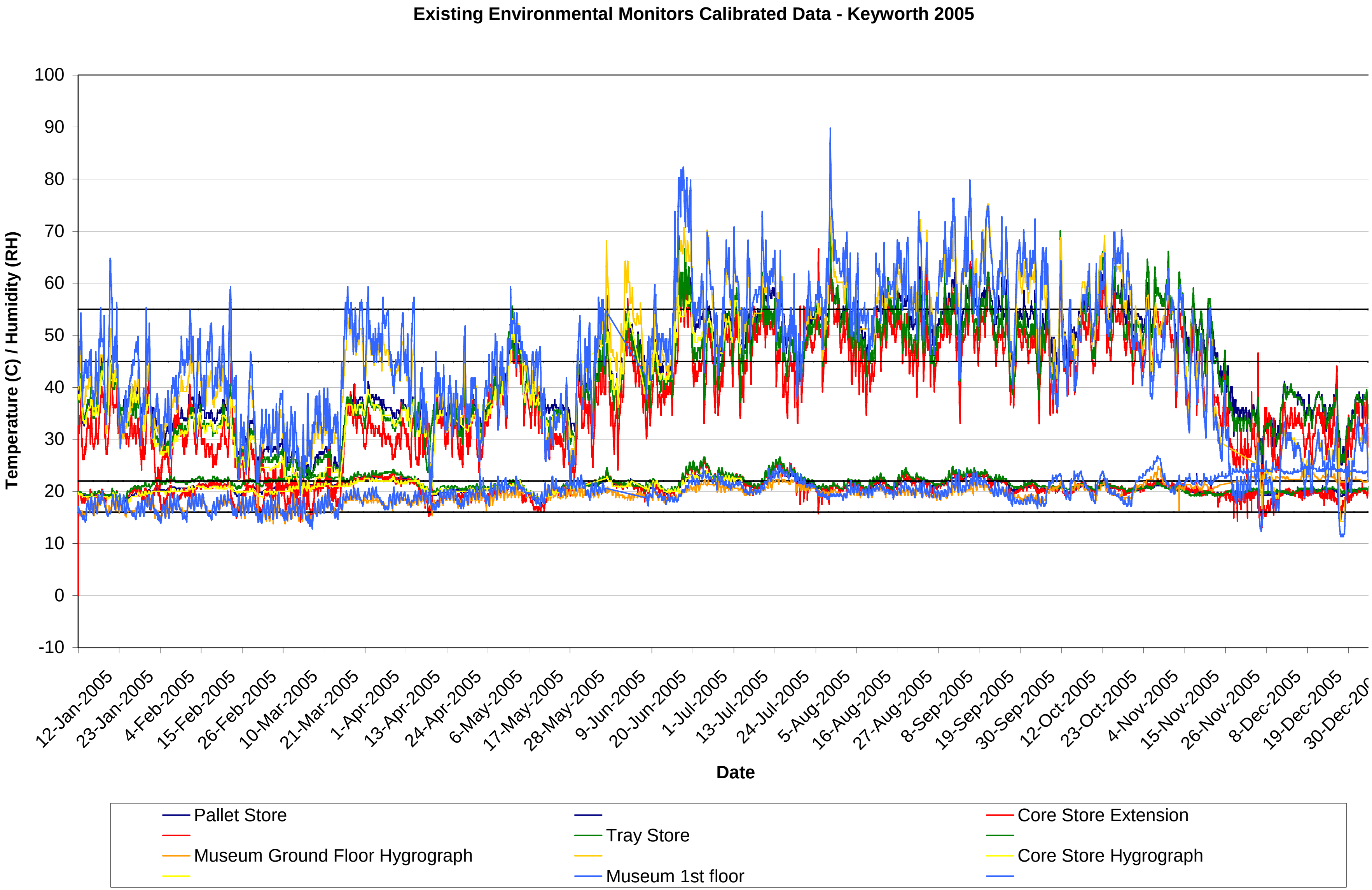

Figure 4: Yearly readings from Existing Environmental Monitors - Keyworth 2005

There ‘appears’ to be a correlation between decreases in external temperatures and internal humidity readings. This can be seen during the winter months from January-March & mid November-December. The most probable cause of these lower humidity readings in comparison to outside may be that the heating system within the building is drying out the atmosphere during these colder months.

The external humidity throughout the year is linked to fluctuations in external temperatures. When the temperature rises and the humidity starts to fall. This can be seen from April through to August. Except for certain occasions during July and August when rainfall amounts were 150% and 225% respectively. For the rest of the seasons (spring, early autumn and winter), the external temperatures fall, whilst the external humidity remains high, due to damp and wet weather.

The internal humidity does not appear to be affected by the external humidity, except during the summer months where high humidity readings are experienced outside, due to high amounts of rainfall. It is also possible that as a result of high temperatures outside that doors and windows would be opened allowing air to circulate and the internal humidity to increase to levels closer to those outside.

Using the graphs on figures 4 & 3, and figures 6 & 5, comparisons can be made between all the monitors, with climatic readings for 2005 and 2004 respectively.

Comparisons in internal temperatures between 2005 and those of 2004, show similar trends for each year. Such similarities are apparent during the summer months with high temperatures occurring, even though the hottest days within the buildings were earlier this year than 2004. It is interesting that; the tray store monitor produced the highest readings during the hottest days of both years. This is probably due to the monitor being on the highest floor, which is closest to the metal roof in the core store, which conducts heats, and we also have to take into account that warm air rises. These are not inaccurate readings but show clearly that the conditions in that type of area affect both temperature and humidity.

Differences occurred at the beginning of the year, when internal temperatures in 2005 were above 16C for longer than in 2004. Whilst other winter months show a general increase in temperature for all the areas monitored compared to 2004.

Internal humidity readings between 2004 & 2005 are not as easy to compare. The humidity does increase during the summer months, within and beyond the recommended 45-55% RH. This rise in humidity occurred later in 2005 (End of May) than 2004 (April). During late 2005, the humidity falls quite sharply, whereas the humidity during 2004 for the same period shows a more gradual decline. Even though there was partial data during 2004 (museum 1st floor monitor), it can be seen that this location had the highest readings for both years, and towards the end of the year showed the lowest readings.

When you compare the external readings for 2004 and 2003 (figures 3 and 5), there are similarities between both years; with high and low temperature readings occurring at similar times, even with slight seasonal variations. As for the humidity values, this too has similar high humidity readings during the spring and winter months, and generally lower humidity readings through the summer, except when heavy rainfall has occurred.

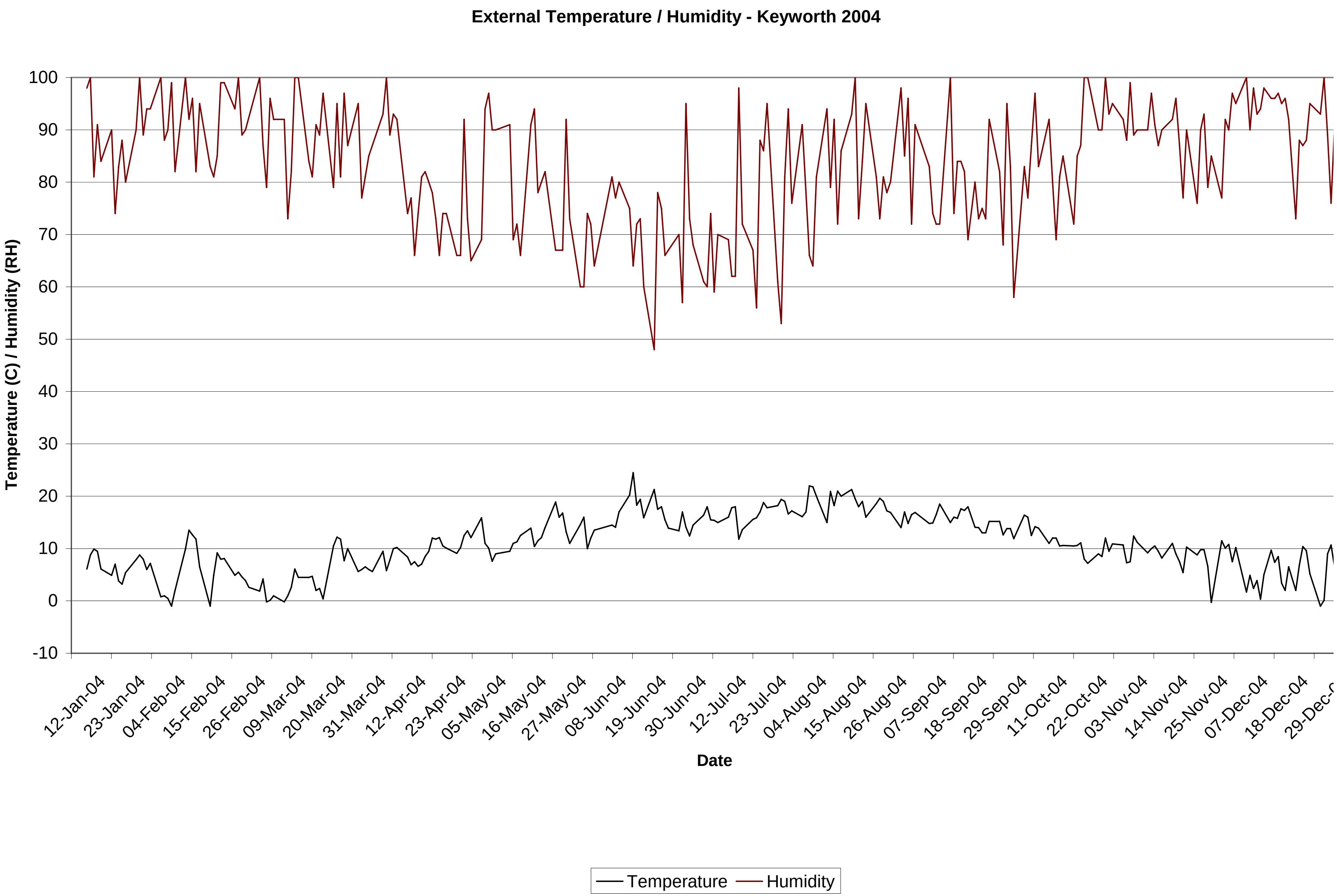

Figure 5: External Temperature and Humidity - Keyworth 2004

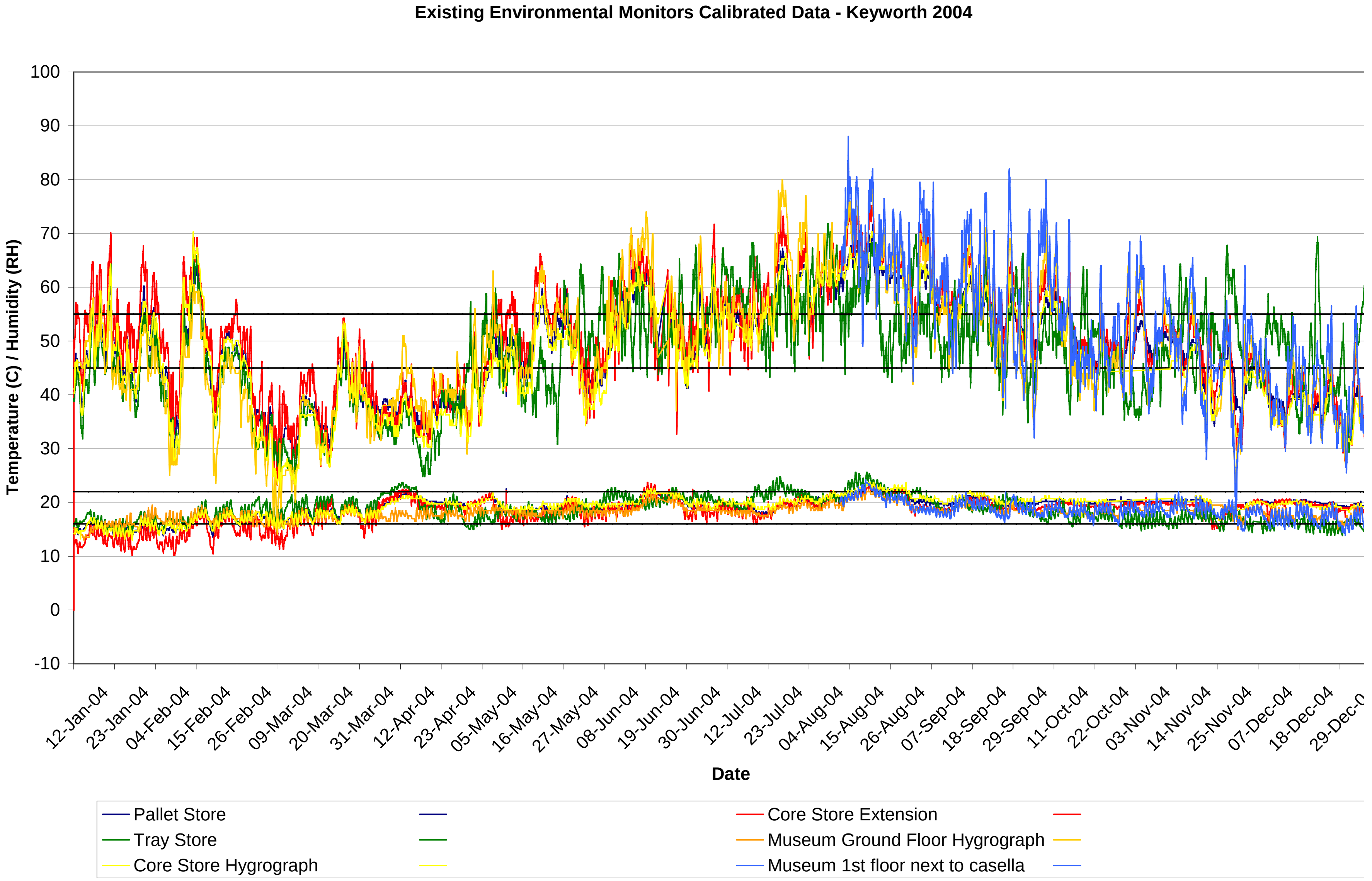

Figure 6: Yearly readings from Environmental Monitors - Keyworth 2004

2.3.1.1 YEARLY CALIBRATED RESULTS SUMMARY

Throughout 2005 there has been very little change in the internal humidity or temperature readings compared with 2004. Except for the winter months where a noticeable decrease in humidity levels was recorded for all the main locations, whilst at the same time a similar decrease in external temperature readings also occurred.

The values fluctuate less during the beginning of the year compared to 2004 for the same period, even though the humidity levels are outside the recommended 45-55% range. Additionally, the humidity readings fall within the mid to upper 45-55% parameter range more often during the summer months than 2004.

One observation is that, the internal temperature through 2005 appears to fall within the 16-22C parameters more often than in 2004, even during the winter months. Interestingly, two periods of high temperatures were recorded during the summer; this is earlier than 2004 but still occurs at a similar time.

Meteorological readings for both years show similar trends throughout the seasons, however a sudden cold snap occurred during November & December 2005, compared to 2004.

One of the higher humidity readings recorded, was on the first floor of the museum compared to other areas, however this became the lowest during the winter months. The lowest temperature readings were recorded again, on the first floor of the museum. This had the highest values during the winter, due to the central heating being adjusted in the museum stairwell. During the hotter summer months, the tray store recorded the highest values for both years, possibly due to its proximity to the core store roof.

It must be remembered that the majority of the collections are stored within microclimates i.e. wooden or plastic trays and boxes. From last year's mini projects, the results have shown that these microclimates do buffer the effects of the surrounding environment in which they are stored to some degree.

2.3.1.2 DISCUSSION OF YEARLY RESULTS THROUGH HISTOGRAMS

To assist the reader in viewing the results, a series of histograms have been produced. It is hoped this will provide a clearer picture than the line graphs, without 30-minute readings being displayed. These graphs are shown as a percentage; for the amount of time each monitor falls within, above or below the recommended parameters for temperature and humidity throughout the year.

Figure 7 shows the temperature ranges for all of the monitors in 2005 as a percentage, whilst Figure 8 shows the comparisons of temperature readings during 2004.

During 2005, all the monitors are within the recommended 16 – 22C range for at least 67% of the time. Comparing these values with readings during 2004, there is a 14% reduction. Even with a decrease, this is an improvement on the 2003 data where values reached a minimum 50%. Over the previous three years, the average minimum reached 68% within the 16 –22C range, so therefore this year is on par. For readings outside the recommended range, this has increased for values greater than 22C, however this has significantly dropped for readings less than 16C. The core store locations (within range) compared to last years are very similar, with only the tray store showing a decrease. These decreases have been offset by increases in values greater than 22C. This has not helped with the high temperatures experienced on occasions during the summer. Both floors of the museum have also noticed a decrease in the acceptable range from last year. With the high external summer temperatures and the fact that the museum central heating was adjusted during the winter, and was not turned off over the site during a autumnal warm spell, are possible contributing factors.

Similar histograms show the humidity ranges for 2005 and 2004, see Figures 9 & 10 respectively. It must be noted that during the beginning of July, the core store hygrograph stopped working, so therefore the readings (figure 9) only show approximately 6 months of data for the core store hygrograph, whereas the other monitors show data for 12 months. If used for comparative purposes would give an inaccurate picture, therefore this has been excluded. From the remaining monitors, all areas are within the minimum recommended 45-55% for at least 24% of the time. This is a decrease from last year by 6%. When comparing the last three years for the same graph, the average minimum reached 29% within the 45-55% range, so therefore a slight decrease. All of the areas have shown an increase in readings below 45%, but a decrease in readings above 55%. This could have been caused by the slightly lower humidity readings experienced outside, together with the mild autumn and the central heating system being on through this period, thus causing the internal atmosphere to dry out across the site.

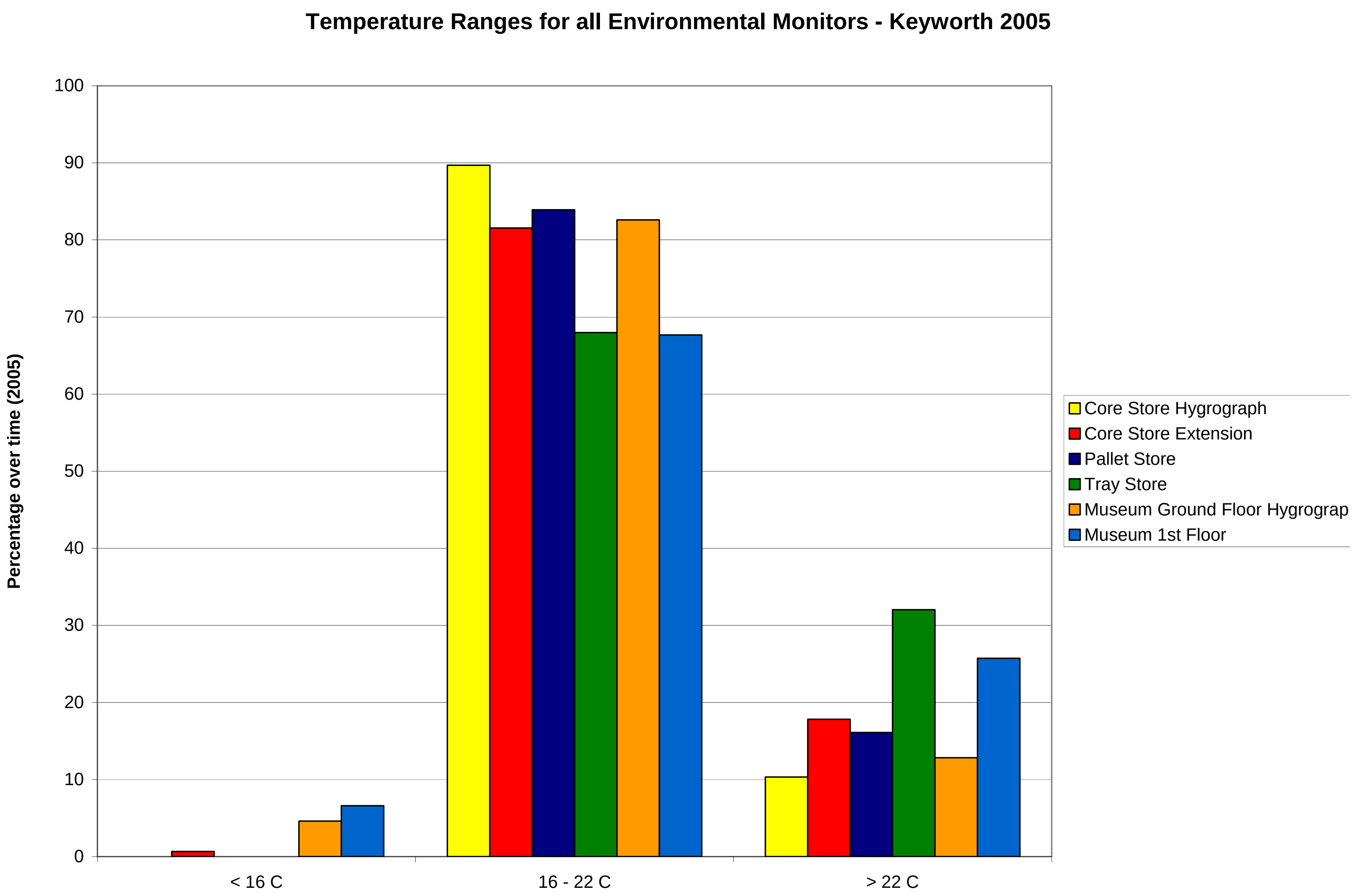

Figure 7: Histogram: Temperature ranges for all existing monitors – Keyworth 2005

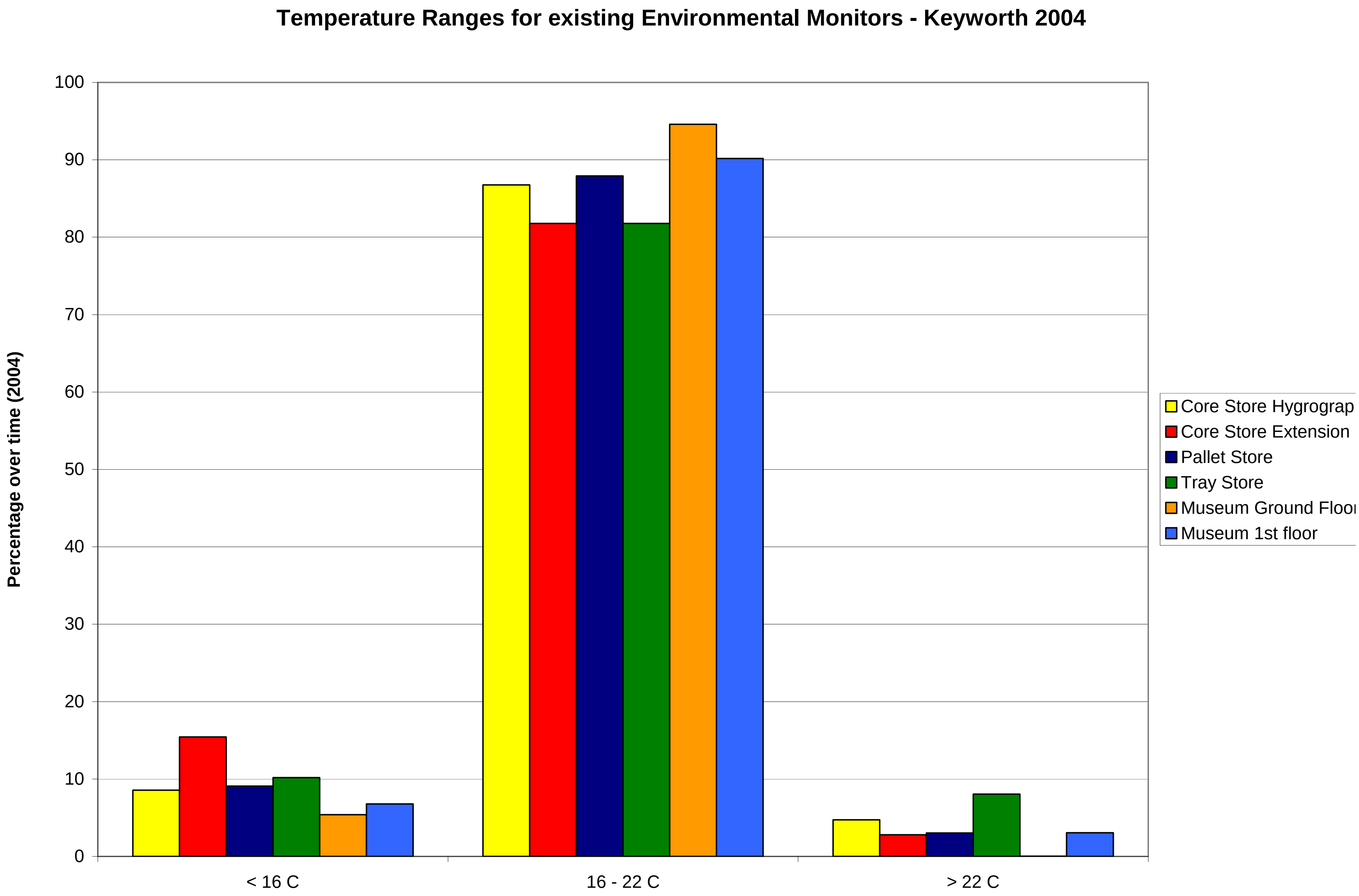

Figure 8: Histogram: Temperature ranges for all existing monitors – Keyworth 2004

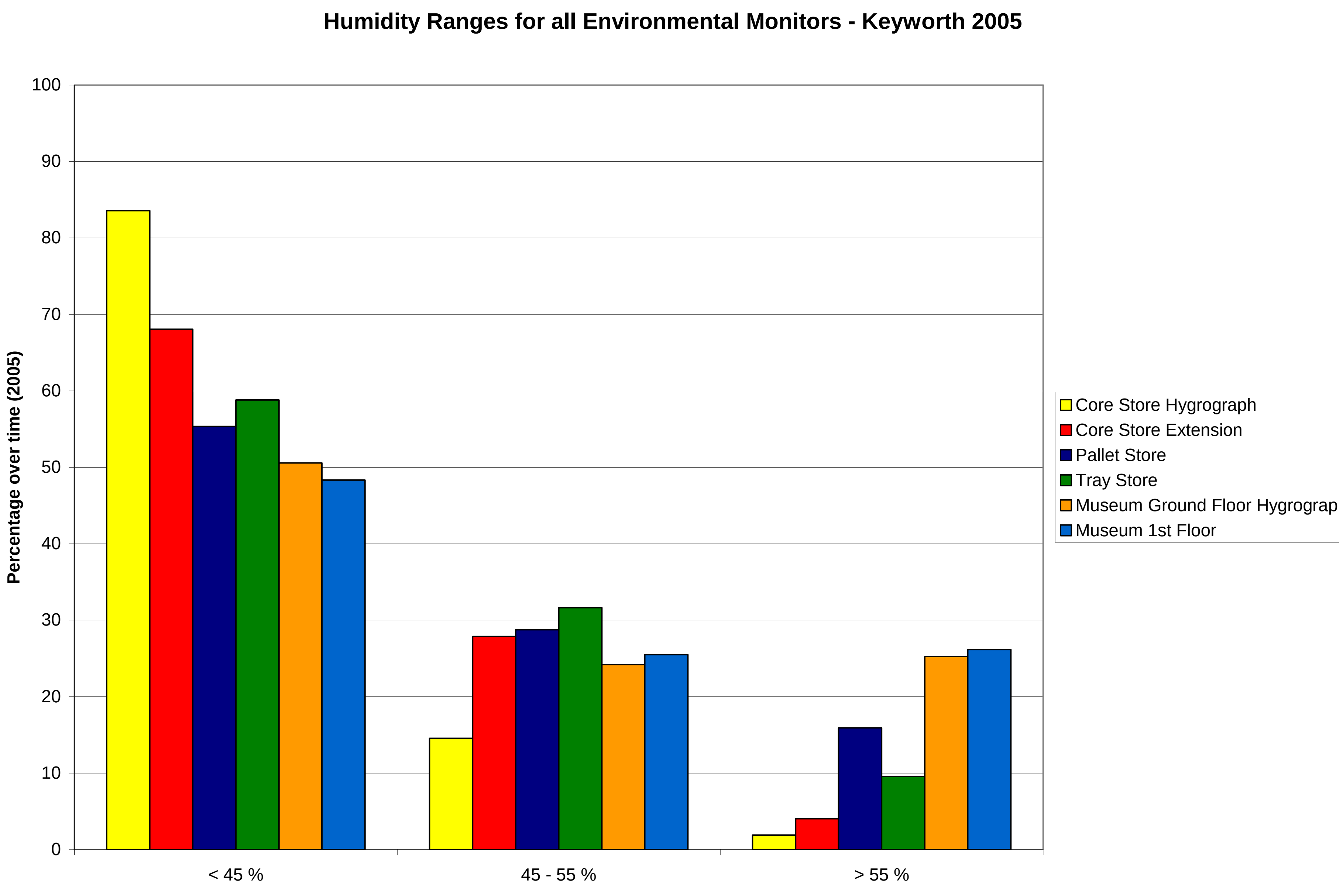

Figure 9:Histogram: Humidity ranges for existing Environmental Monitors – Keyworth 2005

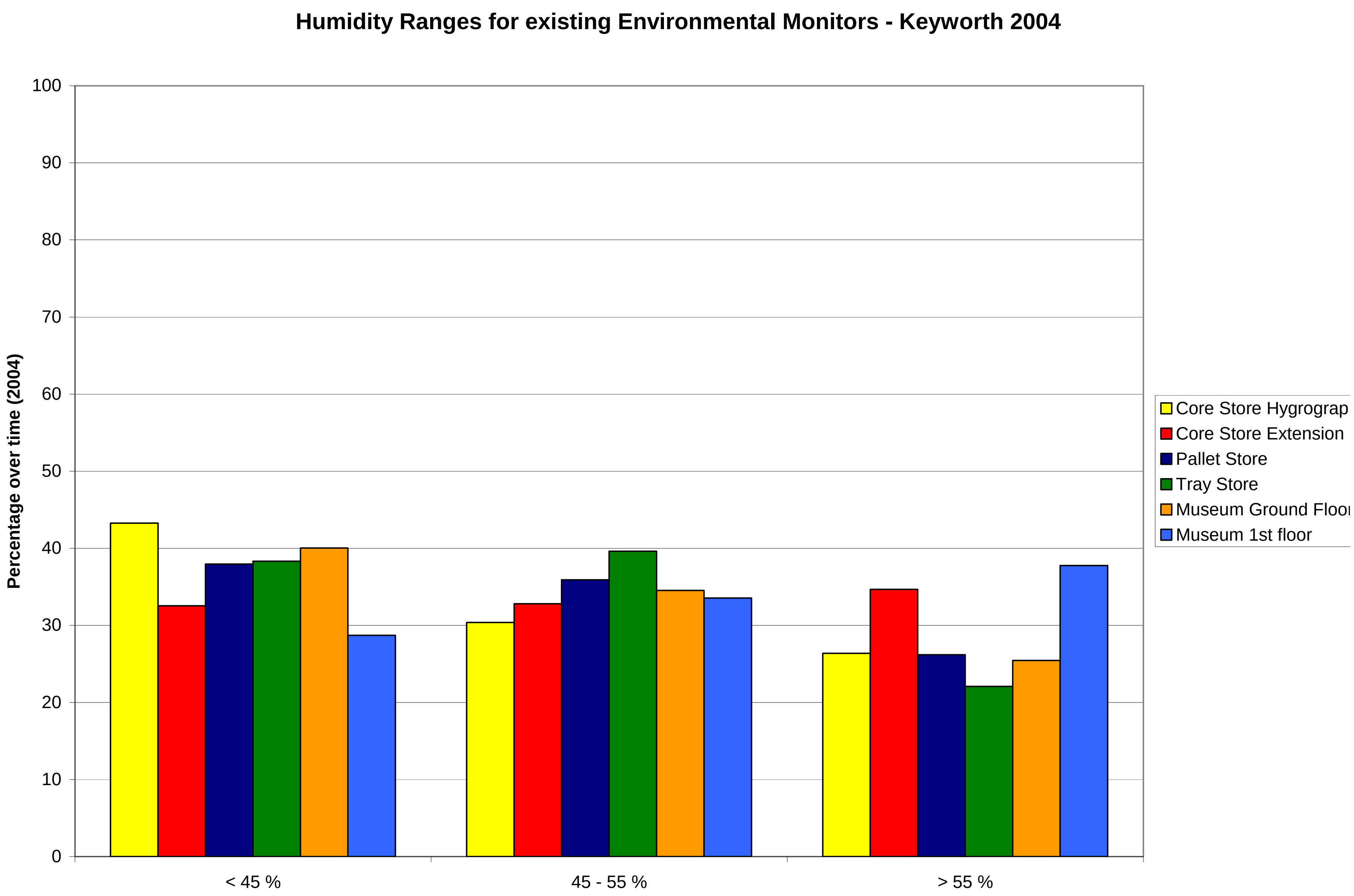

Figure 10: Histogram: Humidity ranges for all existing Environmental Monitors – Keyworth 2004

2.4 ADDITIONAL MONITORS WITHIN THE CORE STORE AREAS 2004

During 2005 funding became available to purchase additional Digitron Monologgers. It was decided to expand the monitoring programme within the museum on a permanent basis, rather than setting up mini projects as in 2002-2003. From March 2005 additional monitors were placed within a museum drawer and in the weather station to provide regular readings.

This year will also be the first year where full annual readings have been taken in the Conservation Laboratory, Library Strong Room and the NGRC. Background information on existing areas and monitors can be found in last years report *Shepherd & Tulloch 2005*, sections 2.4–2.7.

2.4.1 Conservation Laboratory & Core Store Main Corridor

It must be noted that the Conservation Laboratory monitor was only in operation from November 2004, therefore annual comparisons between 2004 and 2005, cannot be made. This also applies to the main corridor in the Core Store where the monitor was set up from August 2004. Additionally, annual comparisons using histograms will show inaccuracies as the Conservation Laboratory and Core Store main corridor only accounts for 2 months and 4 months of data respectively in 2004, compared to 12 months of data in 2005.

2.4.1.1 Conservation Laboratory & Core Store Main Corridor Results

A graph displaying the results for both the Laboratory and the main corridor is shown in Figure 11.

The monitors within the conservation laboratory and main corridor show similar readings throughout the year, with temperatures fluctuating regularly around the 22C mark. During January through to May, both areas are showing regular patterns on a weekly basis. Looking more closely at the data, the low troughs coincide with weekend dates, when the central heating system would be turned off during this time. Such pronounced activity then ceases around May, when the heating is turned off during the summer months. This occurrence is also noticeable within the museum, but not from the other core store monitors. A reason for this could be that it is more noticeable with smaller storage areas such as the museum & conservation laboratory, where the influence of smaller fluctuations in temperature is more apparent. These periods of change are subtler during the summer, and difficult to detect during the latter winter months. A factor for this could be due to an overhaul of the heating system within the core store and conservation laboratory during late summer.

For both monitors during 2005, show major fluctuations in humidity readings, with lower readings below 45%RH in the winter months, whilst during the summer readings situated within the 45-55% range and often reaching 60% RH. A recommendation in the 2004 report suggested measures to try and increase the humidity within the conservation laboratory. A trial period was carried out during March to May, when humidity levels were noticeably low. A glass beaker placed on a shelf, was filled with a measured quantity of water on a weekly basis and readings were taken. On average over this period, there was an average of 18.07% water loss into the atmosphere. From the graph, it can be seen that an increase in humidity was recorded. Unfortunately comparisons with the core store corridor cannot be made due the humidity sensor providing unreliable readings. I believe that this was successful, as elevated humidity readings were recorded in the laboratory, which was in a windowless enclosed room. However, a repeat of this experiment could be beneficial.

Using figure 12, even though the core store corridor and conservation laboratory provides 4 and 2 months of graphed data respectively. Both graphs show that the temperature is similar for both areas; around the 22C mark. Whereas the humidity for the corridor has dropped significantly during late autumn, compared to 2004. Such a decrease coincides with similar results across the site, and a cold snap measured with external monitors.

Figures 13 and 14 show that the laboratory and main corridor were within the 16-22C temperature ranges for 44% and 37% of the time respectively. With no readings recorded below 16C. However readings above 22C accounted for a minimum of 55% for that time.

The humidity readings show that both areas are within the recommended range for general geological conditions for at least 20% of the time. Where the majority of the time outside these ranges occurs below the 45% marker for at least 59% of the time

2.4.1.2 CONSERVATION LABORATORY & CORE STORE MAIN CORRIDOR SUMMARY

Each area has shown similarities throughout the years, with readings appearing within and outside the parameters for both temperature and humidity. Temperature readings have been affected by the heating system over the weekends during the beginning of the year. Such fluctuations were not as pronounced during the autumn and winter due to an overhaul of the heating within the core store.

Humidity readings have shown an improvement during a test period to try and increase the humidity within the conservation laboratory, however further trials are recommended.

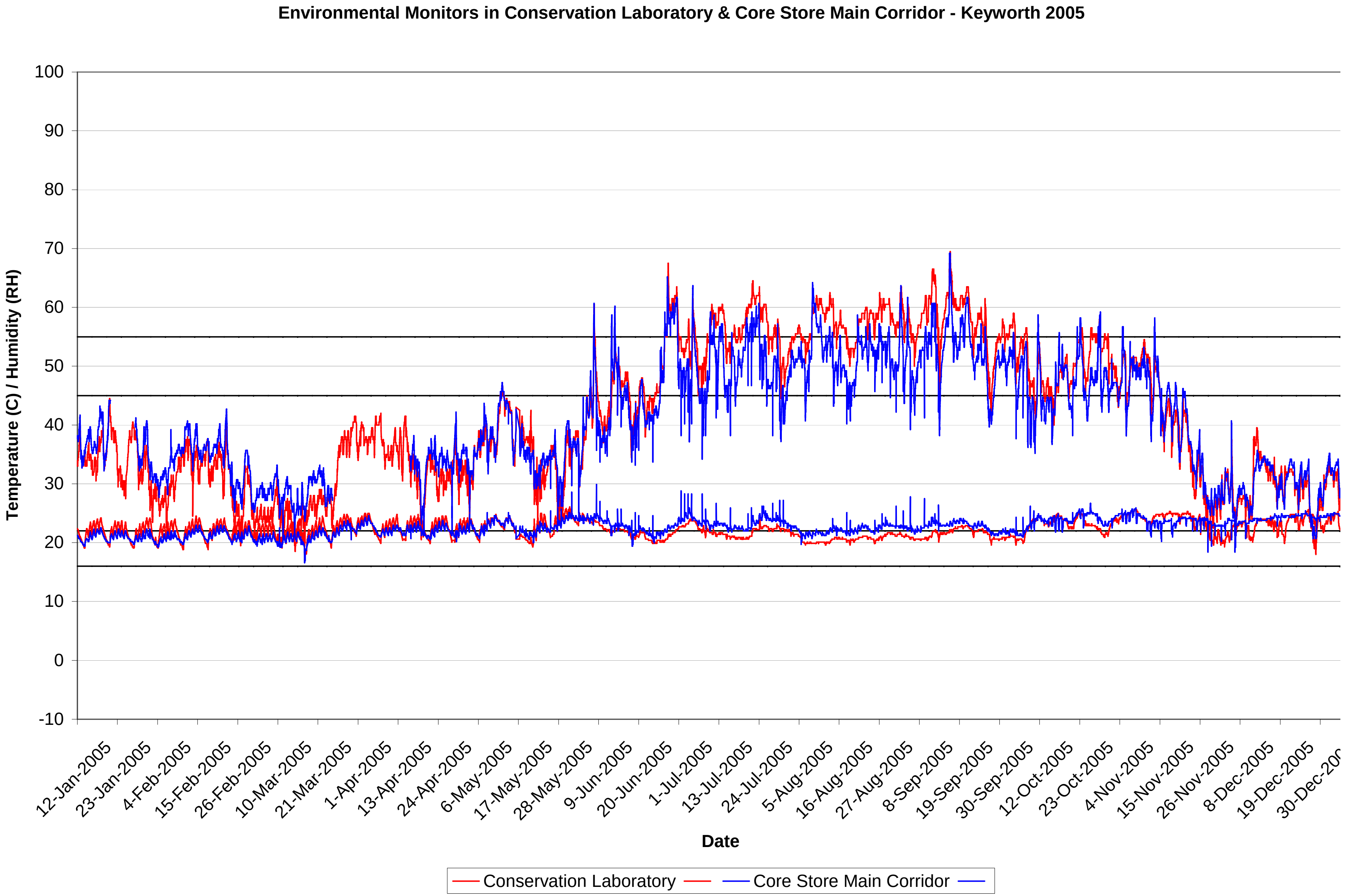

Figure 11: Temperature & humidity- Conservation Laboratory & the Main Corridor of the Core Store 2005

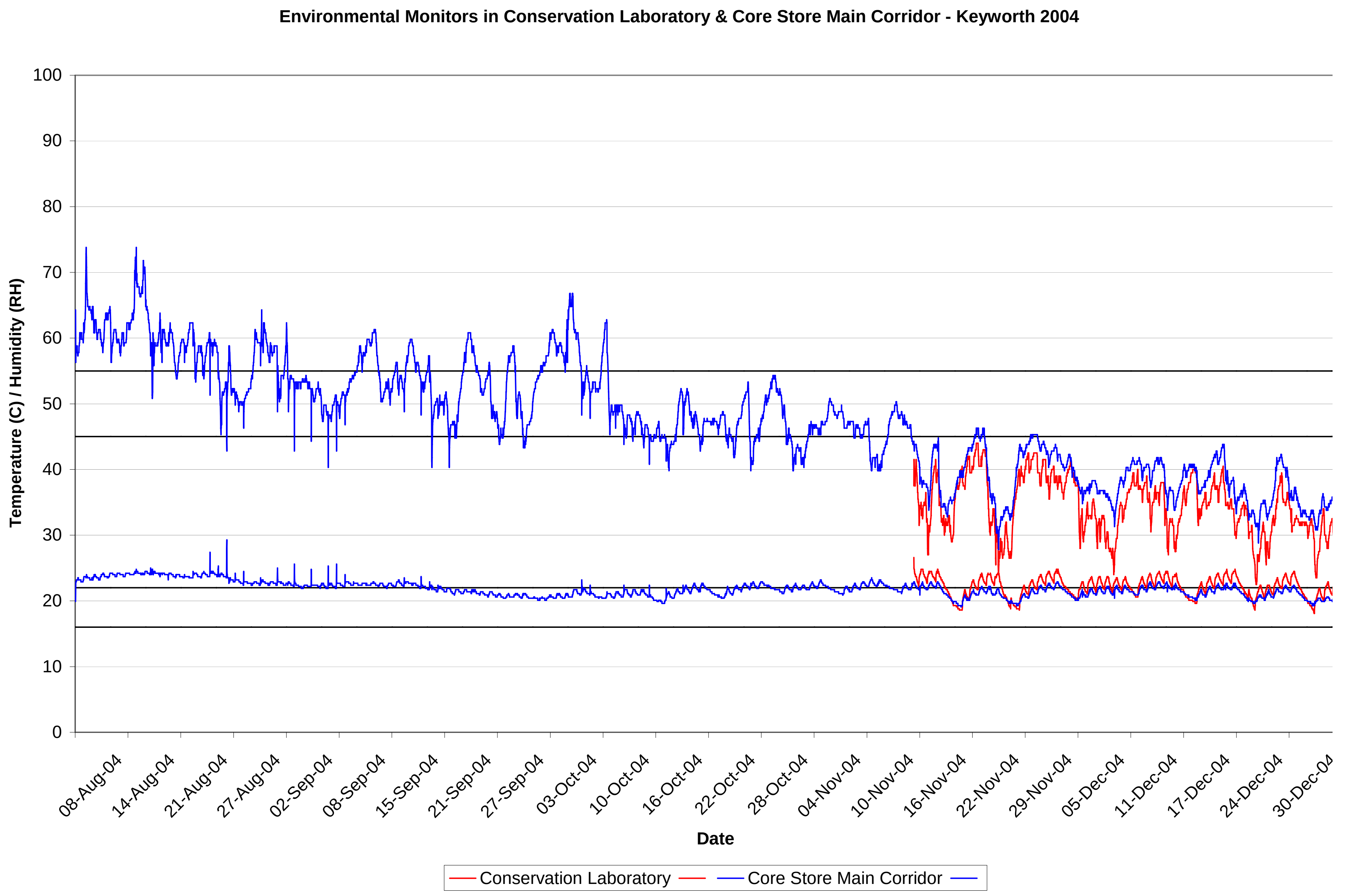

Figure 12: Temperature & humidity- Conservation Laboratory & the Main Corridor of the Core Store 2004

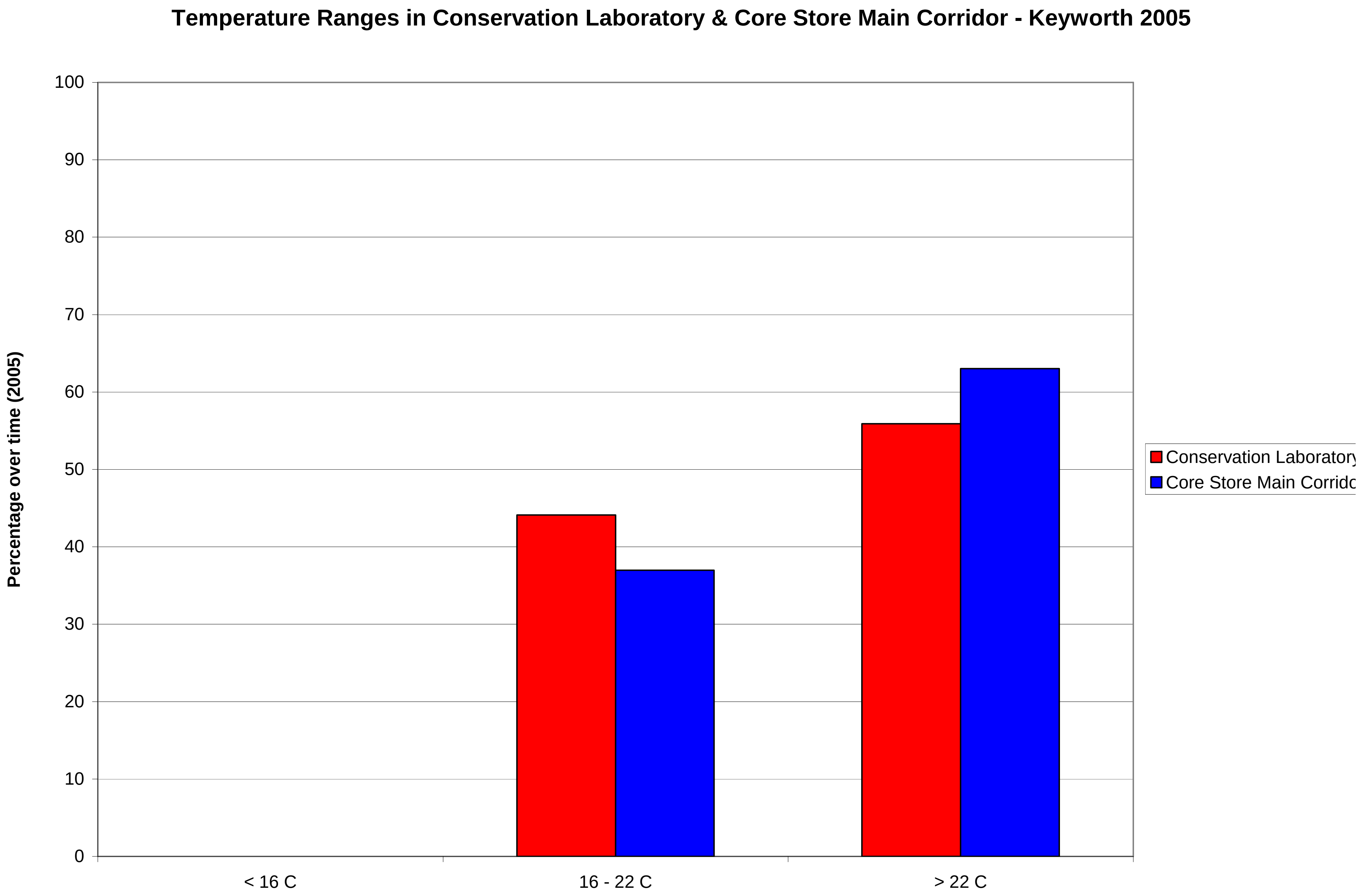

Figure 13: Histogram: Temperature ranges for the Conservation Laboratory & Core Store Main Corridor 2005

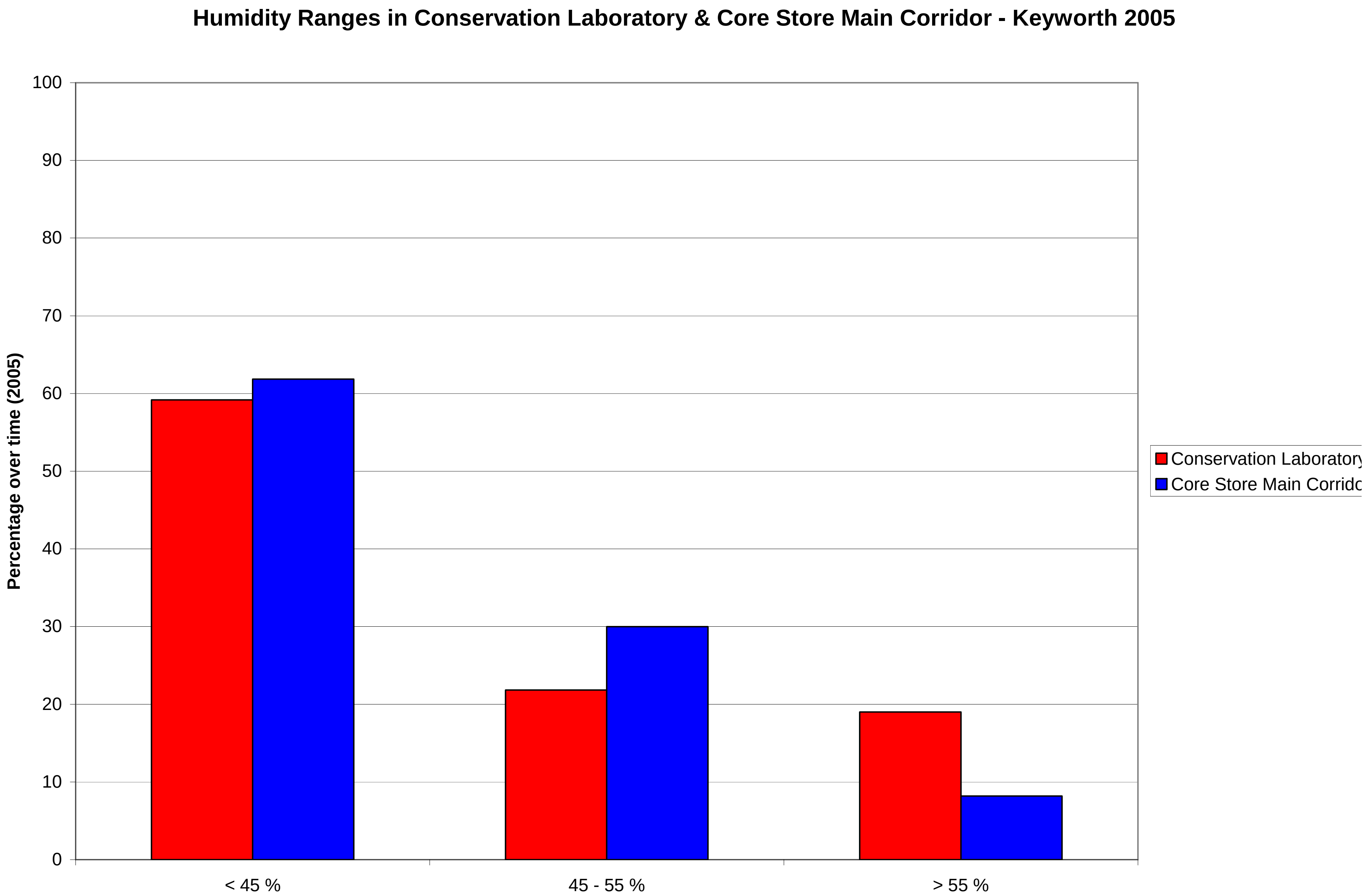

Figure 14: Histogram: Humidity ranges for the Conservation Laboratory & Core Store Main Corridor 2005

2.4.2 Cold Stores

Readings for the Cold Store only commenced during the latter part of June 2004, therefore true annual comparisons between this year and 2004, cannot be made. Additionally, annual comparisons using histograms will show inaccuracies as last year's data only accounts for 6 and half months, compared to 12 months in 2005.

2.4.2.1 Cold Store No. 2 Results

From figures 15 and 17, the graphs show that the temperature is within the recommended parameter of 4C (+/- 2C) for 99% of the time. There are occasions where elevated temperatures have occurred throughout the year, these coincidently have lowered the humidity at the same time. After checking the data, these coincide when BGS staff was using the cold store. After these periods of use, the readings quickly return back to normal. This years data has shown there was a slight improvement compared to last years data (figures 16 and 18) by 6%, with even less time being spend below 2C. Even though there is no recommended humidity range for the cold store, these remain constant between 75% and 92 %RH, similar to readings in 2004.

2.4.2.2 Cold Store No. 2 Summary

Using both last year's partial and this year's full data, it can be seen that the cold store is performing well in maintaining the material stored, to the recommended 4C (+/-2C) parameter. Even though high summer temperatures and regular usage of the Cold Store do not seem to affect the overall conditions.

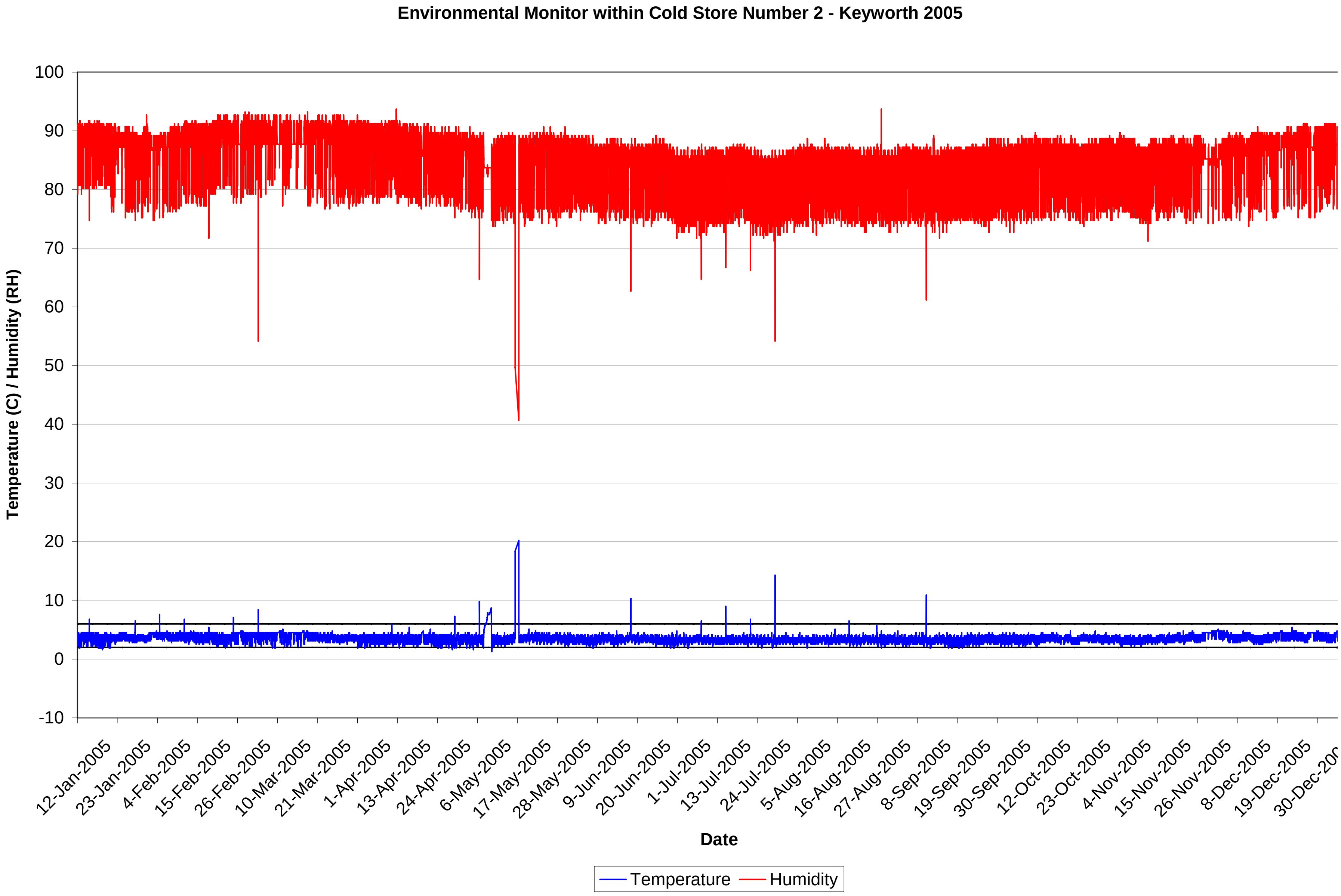

Figure 15: Temperature& humidity readings within Cold Store No. 2 - 2005

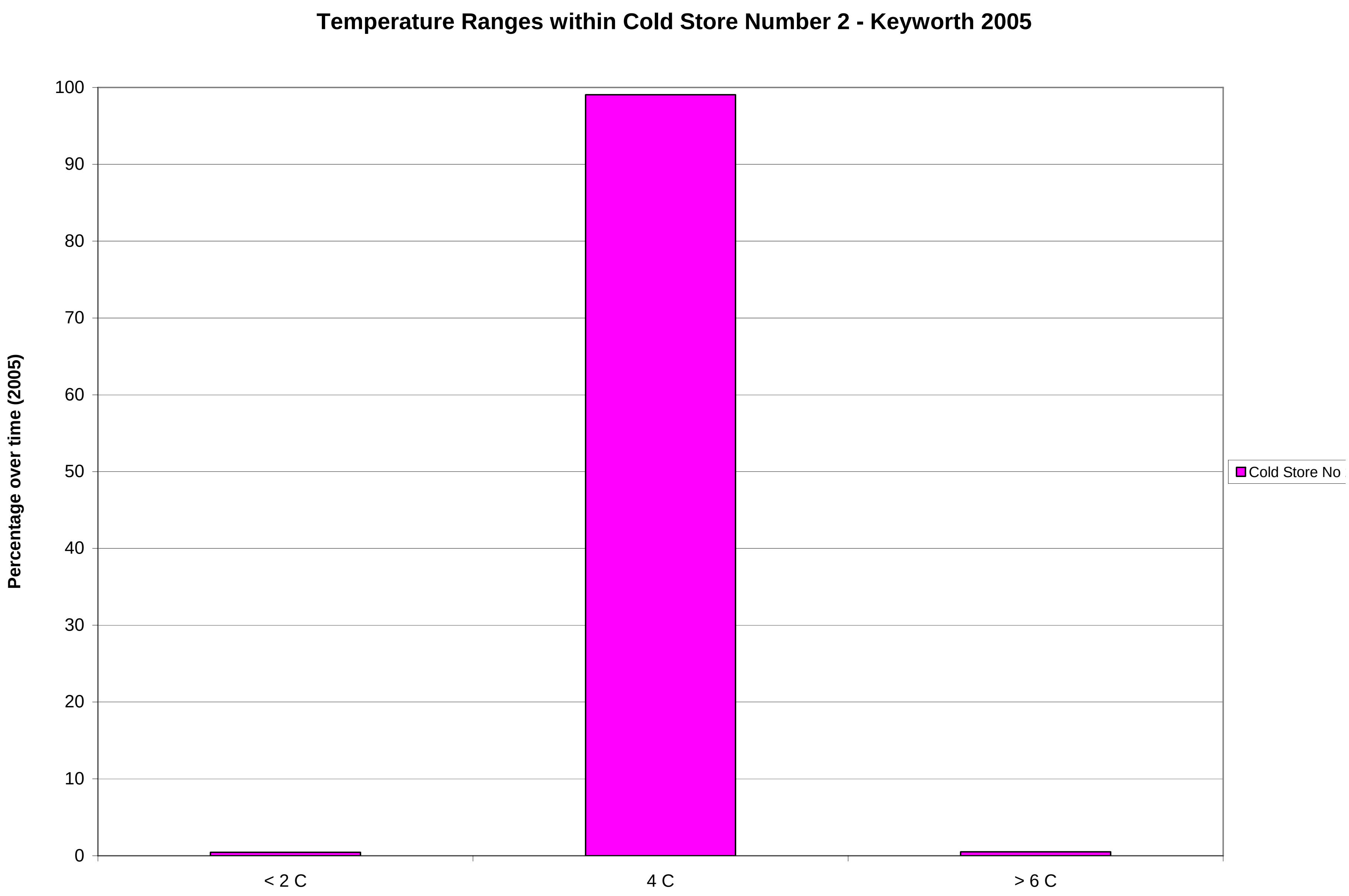

Figure 16: Histogram: Temperature ranges for the Cold Store No.2 - 2005

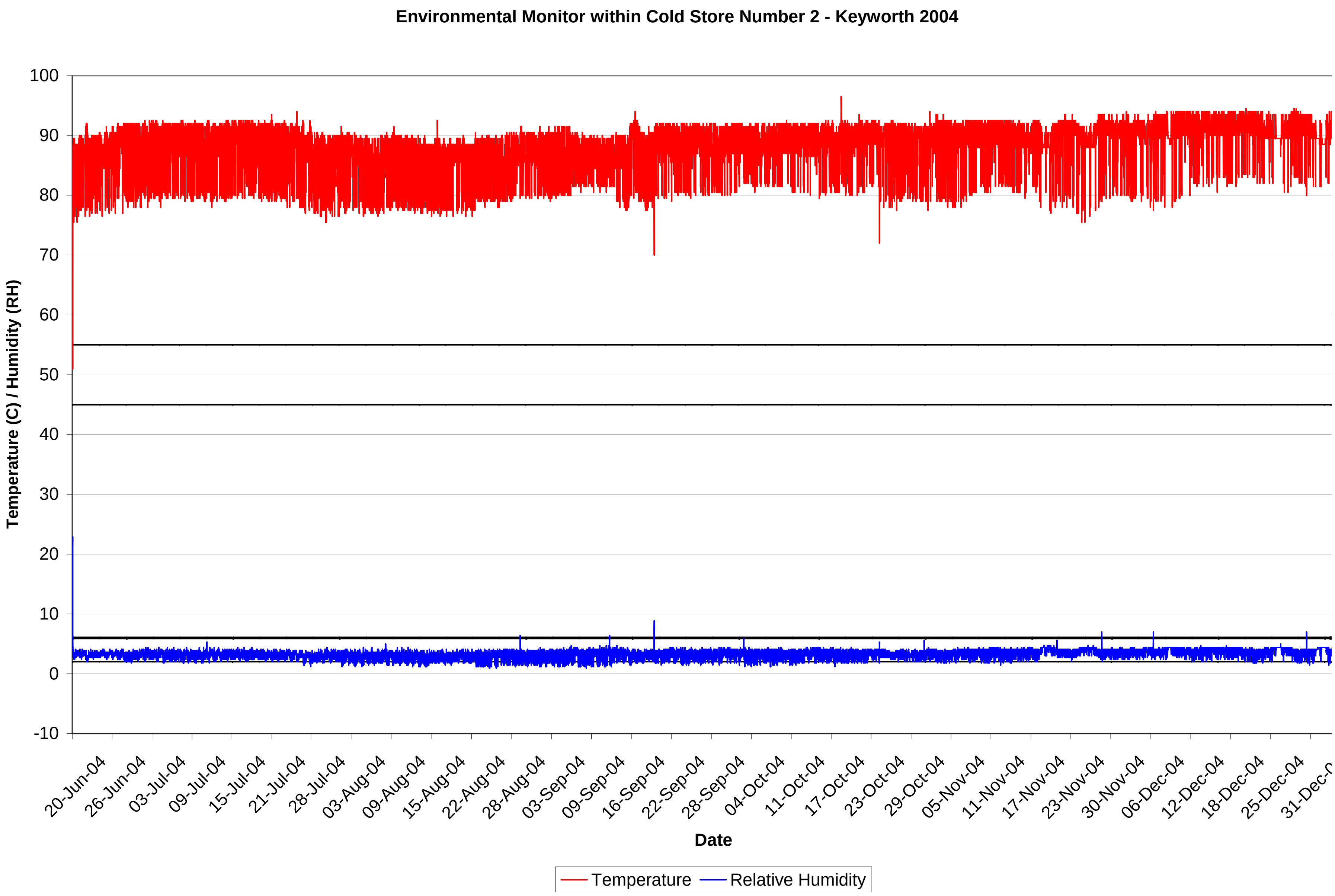

Figure 17: Temperature& humidity readings within Cold Store No. 2 - 2004

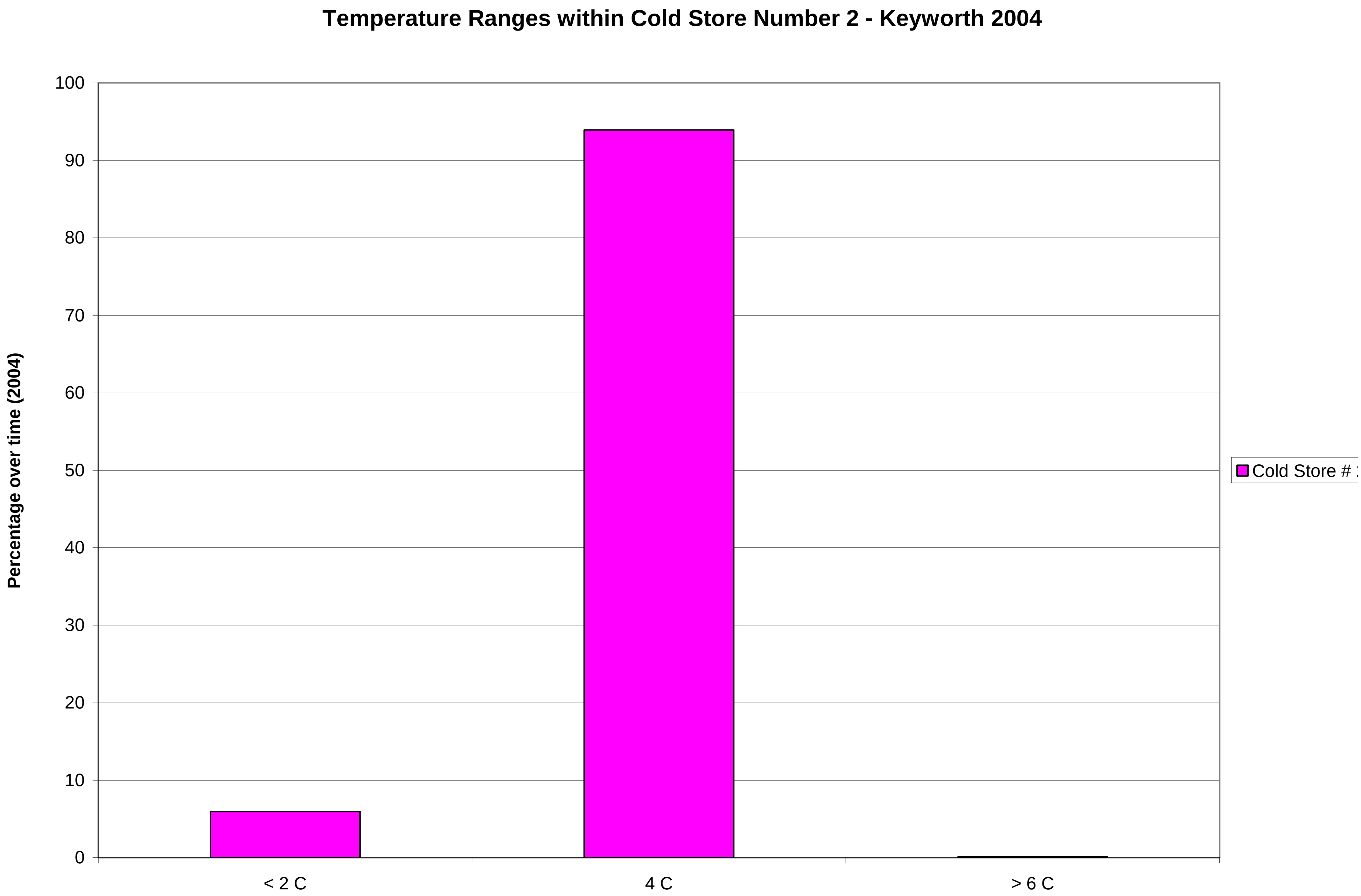

Figure 18: Histogram: Temperature ranges for the Cold Store No.2 - 2004

2.4.3 Comparisons for all monitors within the Core Store Area

During this chapter, there have been many different graphs for many different localities; therefore it is difficult to make general comparisons throughout the core store. This has been simplified using graph, figure 19, which shows the amount of time within the associated recommended ranges, for all the localities, during 2005 and 2004. Please note that the conservation laboratory, core store main corridor and cold store during 2004 were recorded over a shorter time period, and thus comparisons with 2005 will be less accurate.

2.4.3.1 Comparisons for all Monitors within the Core Store Area discussion

The graph shows that the temperature in most areas is within the recommended parameters for at least 68% of the time. This does not apply to the conservation laboratory or the main corridor in the core store, where readings reached an average of 40%, 10% down from last year. The humidity readings during 2005, where full data exists; excluding the core store hygrograph, shows on average all the monitors are within the recommended ranges for 28% of the time; 10% down on 2004. These values are low and cause some concern, but it must be remembered that the majority of the material is contained within trays or core boxes. Thus helping to reduce the effects the surrounding environment has on the material.

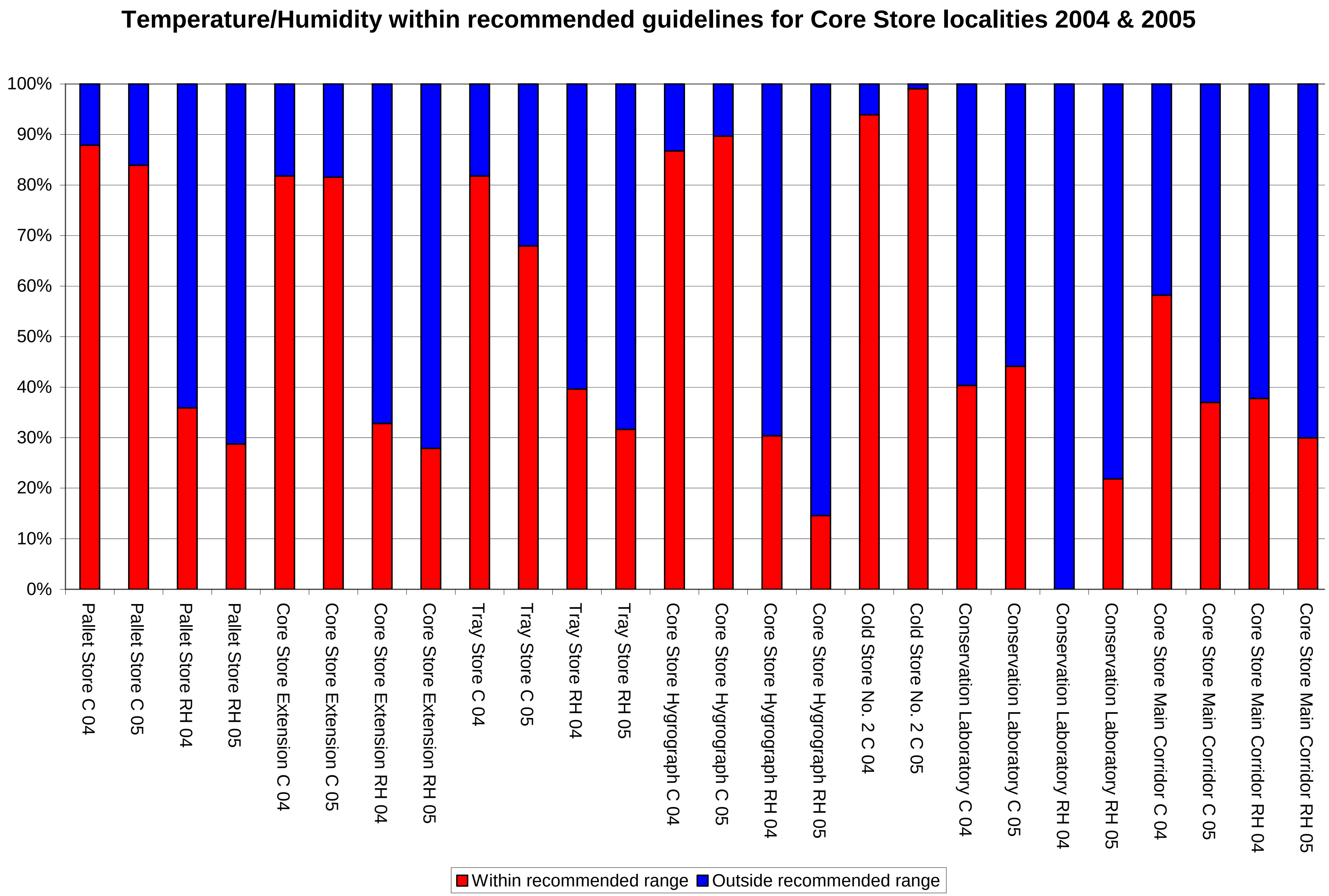

Figure 19: Temperature & humidity within guidelines for Core Store locations 2004-2005

2.5 ADDITIONAL MONITORS WITHIN THE MUSEUM 2004

Like the core store area, additional monitors have been placed around areas within the museum to monitor the effects on certain material more closely. Each area together with the results will be discussed within this chapter.

2.5.1 Museum Sub-fossil Bone and the Museum Mahogany Cabinet

As discussed in last years report *Shepherd & Tulloch, 2004*, most of the museum fossils are stored within Mahogany cabinets, or glass wall cabinets, therefore it was decided to house an additional monologger in a museum cabinet drawer. This has previously been carried out as a short mini project, *Shepherd & Tulloch, 2002-2003*. Recording environmental changes within a cabinet on a permanent basis, with existing monitors, would give us comparative data for inside and outside of the cabinets within the museum environment.

The new monologger was placed within a mahogany drawer (99/32), on the first floor of the museum, which contained Ammonites from the Middle (Lias) Jurassic. This monitor was activated on the 6th May 2005. A suite of monitors within the museum now comprises of:

Monitor at the rear of the museum (First Floor)

Monitor within cabinet drawer (99/32) (First Floor)

A Thermohygrograph along the first aisle (Ground Floor)

Monitor above wall cabinet, next to sub-fossil bone (Ground Floor)

Plate 1: Museum Mahogany Cabinet

The parameters used for the storage of sub-fossil bone in last year's report *Shepherd & Tulloch, 2004*, as stated by *Doughty & Brunton, (1993)*, should be between 16-22C and not below 40% RH. Even though these parameters are correct, I believe that the humidity range is a little unspecific. Therefore, this year it was decided to use the parameters as stipulated by Child, (1994), which states for sub-fossil bone the ideal parameters should be between 18-22C and 50-55% RH.

The monitoring for the Museum cabinet commenced on 6 May 2005, just after the calibration period. It must be noted that comparisons for histograms between this monitor and other museum locations will be inaccurate, as only eight months of data was recorded for the museum cabinet, compared to 12 months for all other areas. From the 9th May, an aisle on the first floor of the Museum was sealed off to allow essential maintenance work to be carried out. This involved re-plastering and painting a section of the ceiling where water from the roof had seeped in, and settling cracks plastered over. This period of work lasted for approximately two weeks, during which time all monitors recorded data.

2.5.1.1 Museum Sub-fossil Bone and the Museum Mahogany Cabinet Results

A graph detailing the results for the Museum Sub-fossil bone and the museum cabinet is shown on figure 20. Additional data has been plotted for comparisons from the thermohygrograph on the ground floor of the museum, and the monologger situated on the first floor of the museum.

It can be seen that the temperature readings for the sub-fossil bone fluctuates throughout the year. During the winter through to mid March, the temperature falls below 18C, by 3C. This then rises on a weekly basis to around 19C. Such periods of low temperature occur during the weekends when the heating is turned off. From Mid March to the beginning of May, there is still a weekly oscillation present, but at a more elevated temperature. From May through to the end of September, the temperature is within the recommended range, even during the hottest days of the summer. During the autumn, the temperature is more erratic, but stabilizes during the winter, just above the 22C mark. Such elevated autumnal readings do coincide with similar occurrences in external temperature readings. It can be seen that all the monitors on both floors of the museum, including the museum cabinet, follows a similar pattern throughout the year. The readings do fall within the 16-22C ranges for storage of general geological collections for most of the time, with the lowest temperatures being recorded in the winter next to the sub-fossil bone, and the highest during the summer recorded on the first floor. There is a noticeable improvement in the stabilization of the temperature readings of the January winter compared to the November – December winter. This is possibly due to the heating in the museum stairwell being adjusted back through the museum, where stairwell temperatures were reaching 27C, and thus raising the temperature within the museum slightly.

Under the specific parameters for sub-fossil bone (50-55% RH), it can be seen that throughout the year, the humidity fails to fall within these ranges. During the winter months, the humidity is well below 50%, whilst during the summer, the values are above 55% RH. The other monitors within the museum follow a similar pattern to the monitor placed with the sub-fossil bone. The only exception is the museum cabinet monitor, where humidity readings are comparatively stable within the 45-55% range, than those outside of the cabinets. From mid-November, there are periods where the humidity plummets towards the humidity levels recorded within the museum. This happens on a weekly basis, and coincides when the monitor is removed from the cabinet, whilst the data is downloaded. Generally there is a gradual decrease in humidity, but not as severe as the other museum monitors, thus showing how effective the cabinets are at buffering either the high or low humidity levels within the museum. Contributing factors that could have led to a decrease in humidity within the museum are, the increase in internal temperatures as a result of the central heating, thus causing the air to become drier, together with the sudden continual cold dry spell experienced outside.

Comparing this years graph with 2004, (Figure 21). There are similarities for all the areas, even though the 1st floor and museum sub-fossil bone only comprise of five months of data. They all show regular weekly fluctuations in temperature through the winter, even though this is not noticeable during winter 2005, due to the increase in internal temperature. The high summer temperatures are also recorded during June & August, similar to those in 2005. The humidity readings show a similar picture with low values appearing during both winter periods. However, a shorter time was recorded in February 2004, whilst a longer duration was recorded in November 2005, with high humidity values recorded through both summers.

Figures 22 & 23 summarise the temperature and humidity within the associated recommended ranges. During 2005, all locations are within their recommended parameters from 63% to 82% of the time. It is interesting to see that the two extreme values belong to the monitors on top of the wall cabinet next to the sub-fossil bone, and along an aisle at bench level, both on the ground floor of the museum. Although only 8 months of data exists for the museum cabinet, this is still showing almost 75% within the 16-22C ranges. The humidity values however show a different picture, monitors that are situated around the museum, are within the parameters for only 10–25% of the time. In contrast, the museum cabinet is 78% of the time within the 45-55% range. The number of readings below the parameters accounts for 48 – 57%, whilst for the museum cabinet this is only 22%. For values above the recommended range, this only accounts for on average, 28% of the time.

2.5.1.2 Museum Sub-fossil Bone and the Museum Mahogany Cabinet Summary

It can be seen throughout the year that there is no difference between each floor with regards to temperature or humidity, each showing fluctuations as the year progresses. The only improvement is where the temperature is more constant during the latter winter months due to an increase in the internal temperature of the building. The museum is being affected by external conditions; this is noticeable during a cold snap towards the end of the year. In comparison, the museum cabinets are performing well as a buffer, displaying more constant humidity readings. The area containing the sub-fossil bone shows sporadic variations in both temperature and humidity. It must be remembered that this area contains only 15 specimens, whilst the remaining sub-fossil bone specimens are housed within 7 glass wall cabinets, which should offer better buffering properties for the specimens. In any case, measures should be taken to try and minimise the effect of the environmental conditions on those remaining specimens.

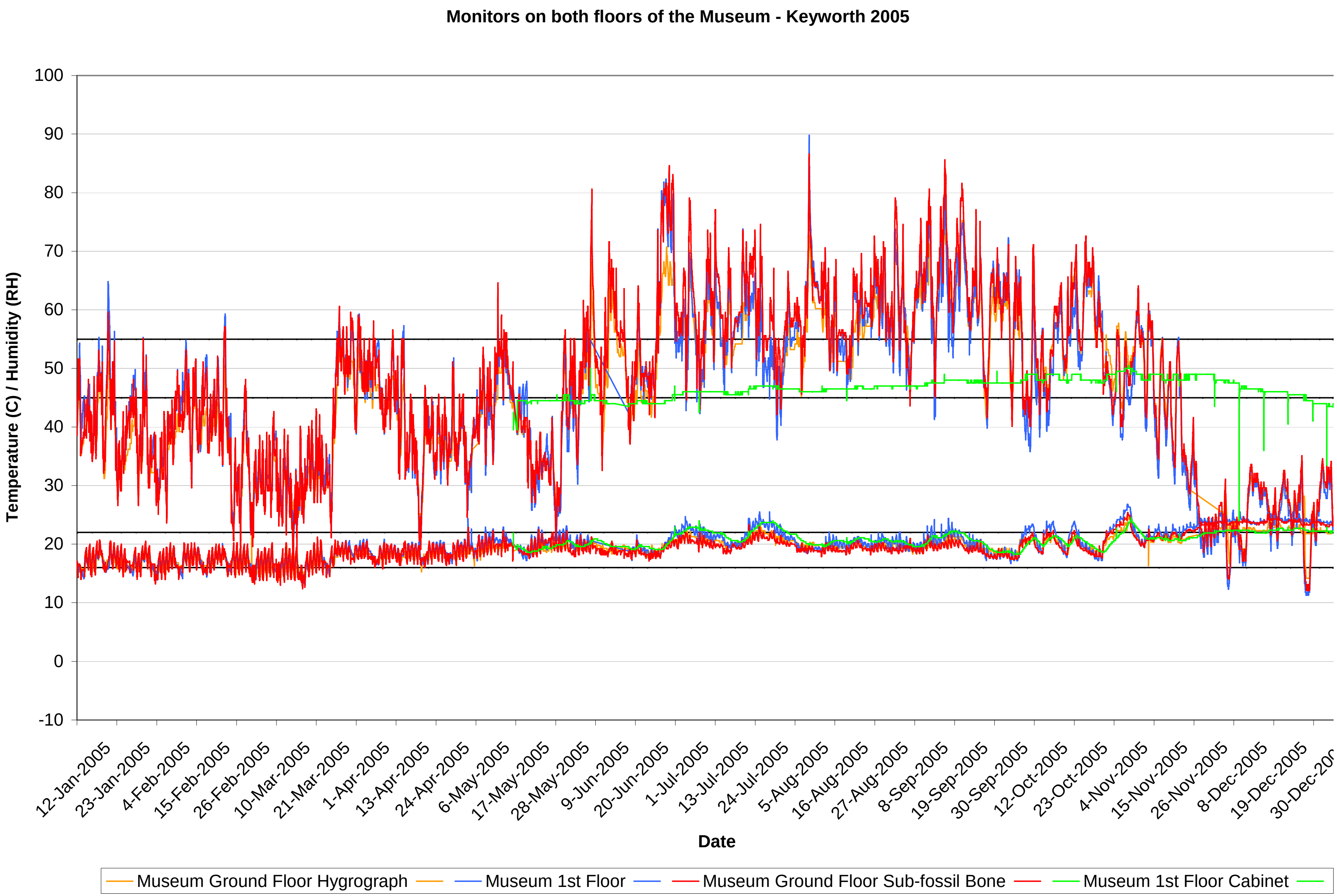

Figure 20: Temperature and humidity readings Museum Sub-fossil bone and Museum Cabinet 2005

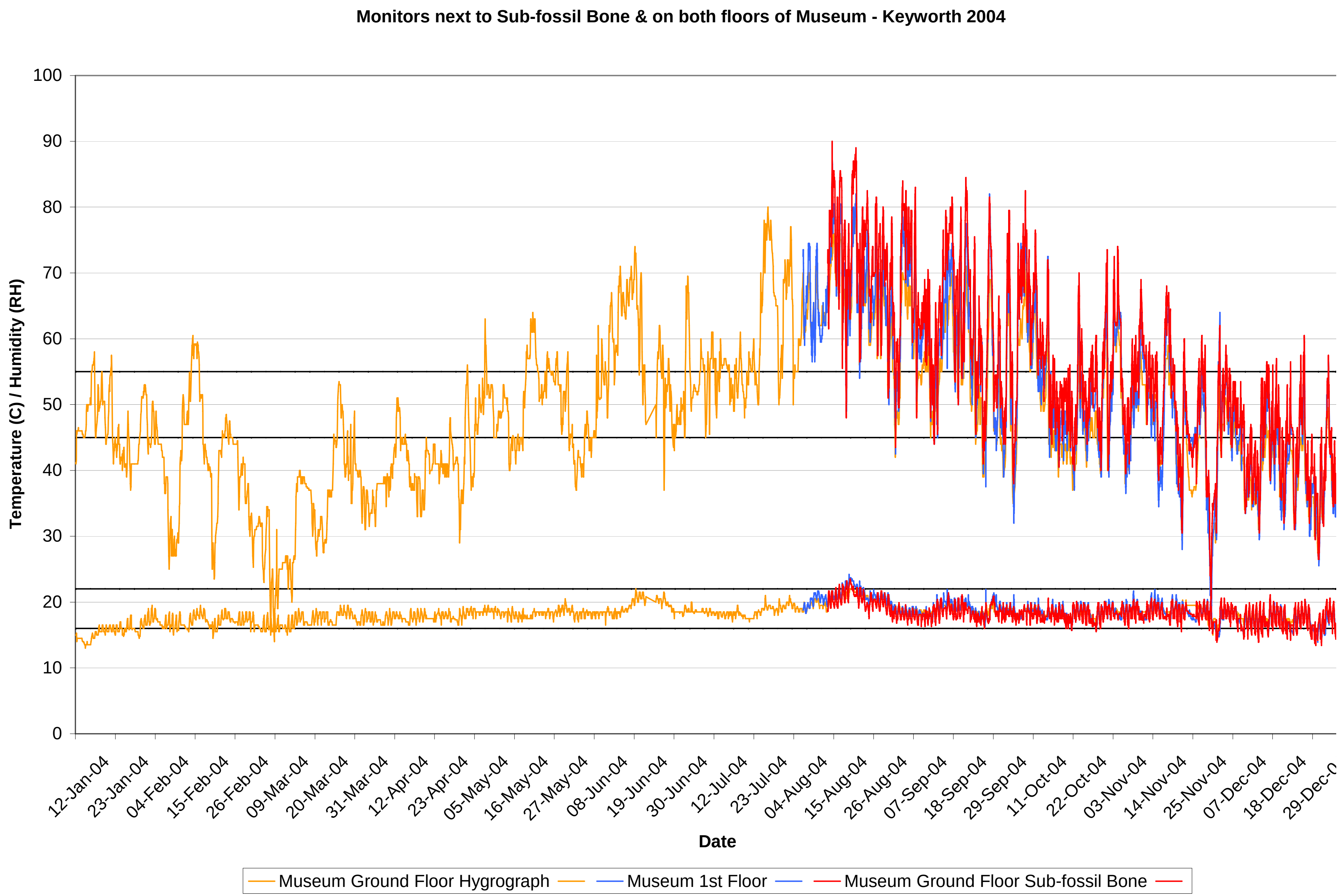

Figure 21: Temperature and humidity readings Museum Sub-fossil bone and Museum Cabinet 2004

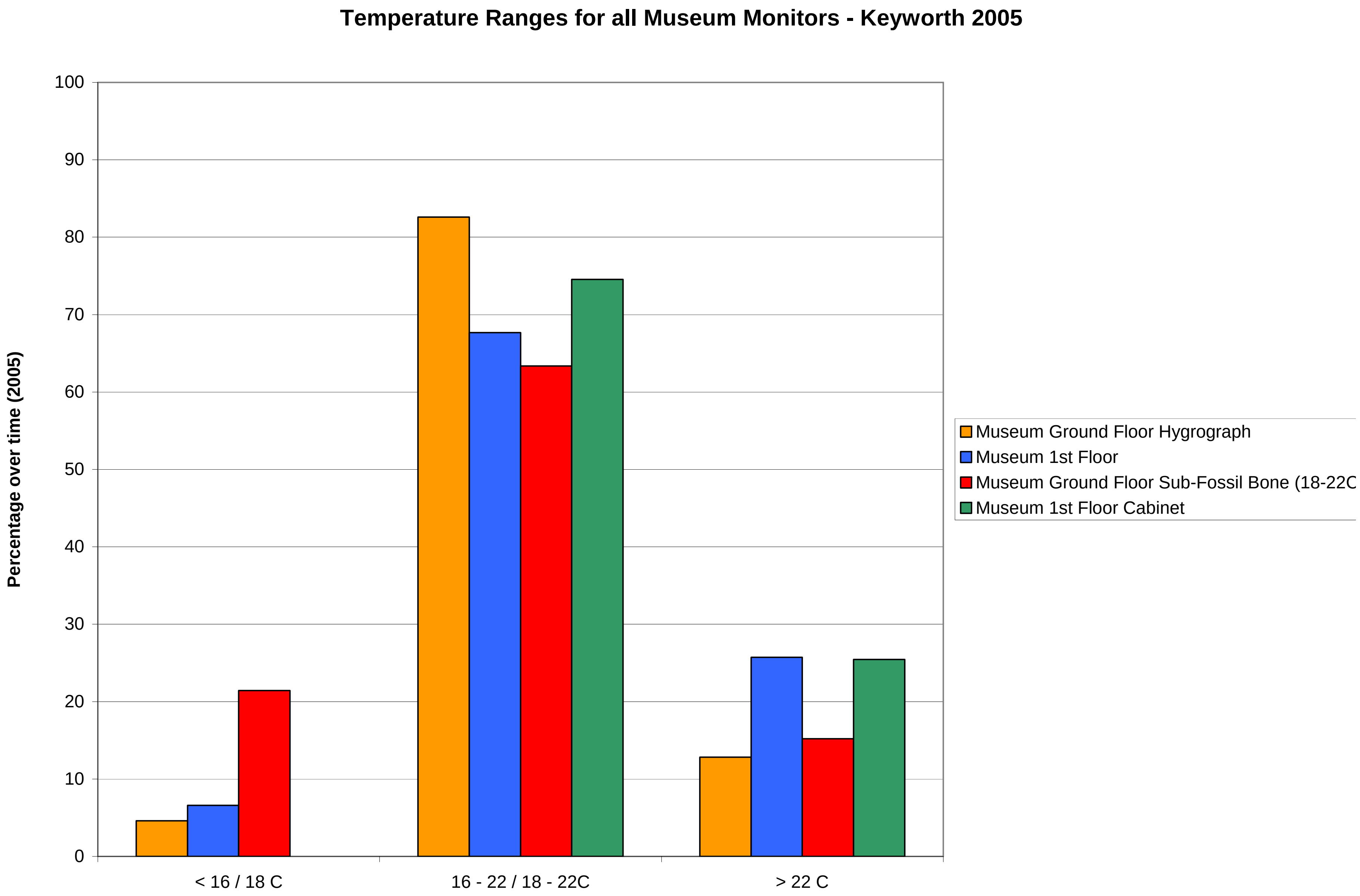

Figure 22: Histogram: Temperature ranges for all Museum monitors 2005

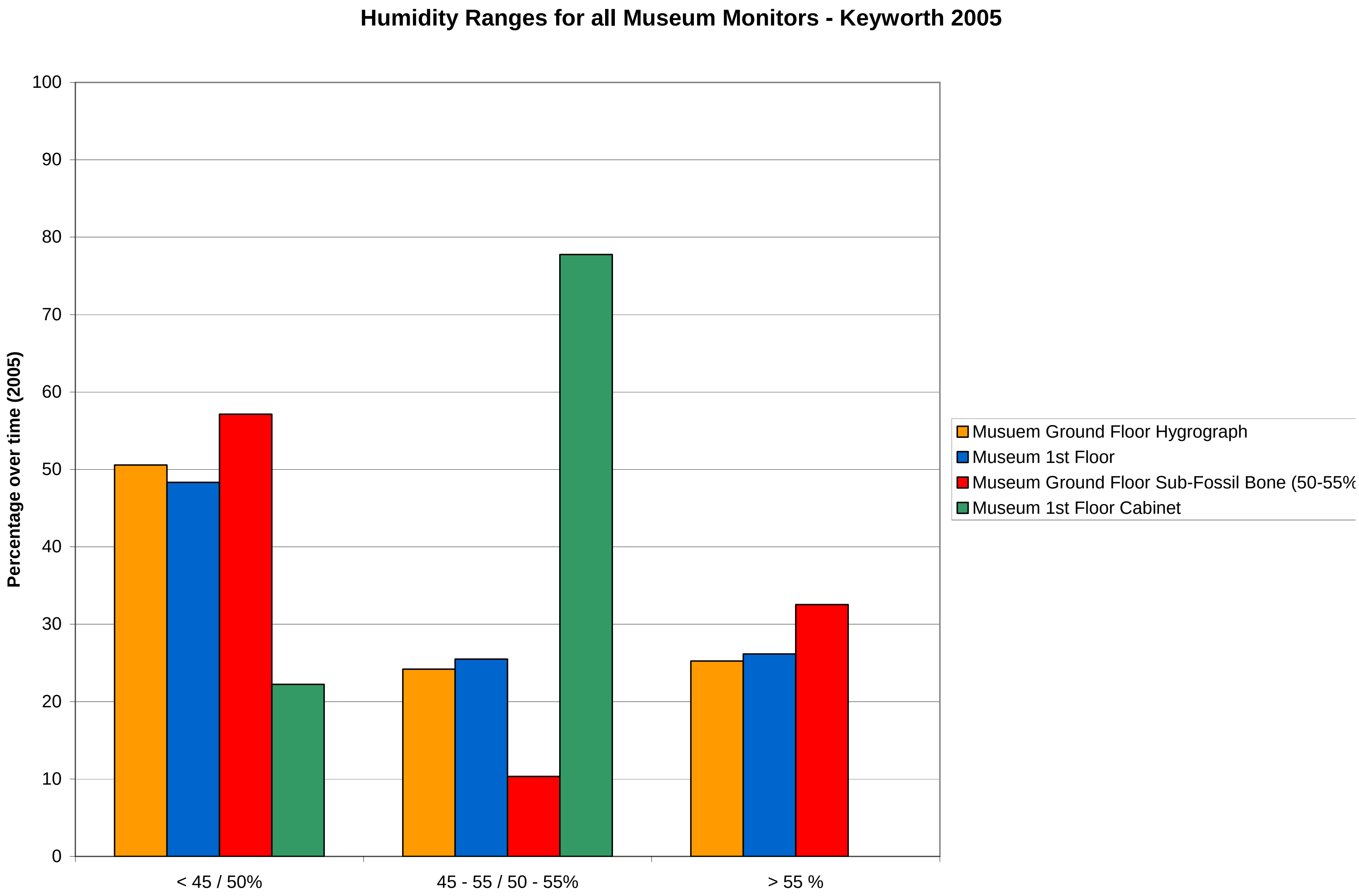

Figure 23: Histogram: Humidity ranges for all Museum monitors 2005

2.5.2 Comparisons for all Monitors within the Museum

To simplify the data for all the localities within the museum during 2005 and 2004, a histogram (Figure 24) has been produced to show the percentage of time within and outside the acceptable parameters. Please note that sub-fossil bone monitor and 1st floor monitor only commenced readings during August 2004; therefore comparisons with 2005 will be inaccurate.

2.5.2.1 Comparisons for all Monitors within the Museum discussion

The graph shows that at least 63% of the time, all locations during 2005 are within the recommended temperature parameters, which is an 8% increase compared to 2004. The humidity levels where full data exists show that the museum ground floor is within the recommended parameters for 24%, is down 10% from last year. For the sub fossil bone, and museum 1st floor, these values are also down by 7% from 2004, showing readings of 10% and 25% respectively. Even though the results for the general museum environment are lower this year, it must be remembered that the majority of the specimens are stored within glass or mahogany cabinets. Readings this year have indicated, that the temperature within the cabinets is comparable to the museum environment, for readings within the recommended range. Whereas the humidity within the cabinets has significantly improved compared to those recorded within the museum.

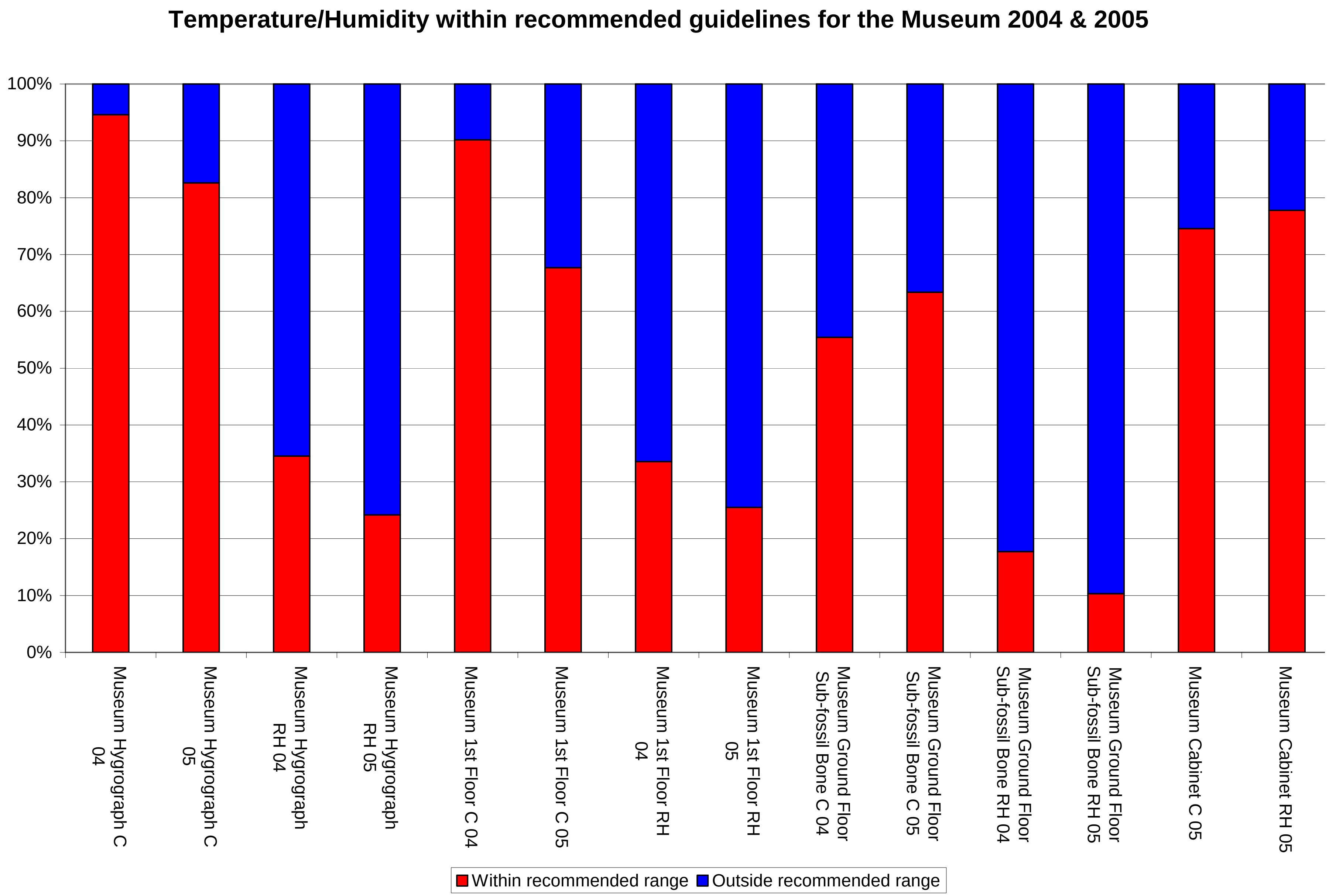

Figure 24:Temperature / Humidity within guidelines for the Museum 2004-2005

2.6 MONITORING WITHIN THE NGRC 2005

The parameters used for the storage of paper records in last year's report *Shepherd & Tulloch, 2004*, as stated by *Doughty & Brunton, (1993)*, should be between 13-18C and between 55-65% RH. As the NGRC is now a place for the deposit of public records, it should now be meeting the following standard, The *British Standard BS 5454:2000*, which recommends for the preservation of archival documents the temperature should between 16-19°C, whilst the Relative Humidity should be between 45-60%.

2.6.1.1 MONITORING WITHIN THE NGRC RESULTS

An annual graph showing all the areas within the NGRC is shown on figure 25, with comparisons under the same parameters for 2004, shown on figure 26.

For each locality within the NGRC, it can be seen that there is a similarity in temperature readings through 2005. From January to mid March, the temperature sits just above 19 degrees at the lowest point, and then peaks around 23 degrees. Changes in temperature like other locations around the site, coincides with when the heating is turned off during the weekends. Daily variations where the temperature increases to a maximum point (on Fridays) can be clearly seen on the record room monitors. The temperature readings for the strong room, although fluctuating, still show subtle trends. From the middle May to throughout the summer, the weekly pattern ceases, due to the heating being turned off across the site. Temperature values now tend to follow those externally. This is noticeable during the two hottest periods of the year during July & August, where similar trends are noticeable within the NGRC and even the Strong Room. Even though the variations are not as pronounced, they still recorded values between 21-24C. During the autumn and winter months, temperatures settle and become less erratic, except for an elevated period within the Records Room at the end of September and a delayed reading in the Strong Room at beginning of October. This noticeable increase coincides with a rise in external temperature and the heating being on across the site. The delayed high temperatures within the Strong Room could be due to the usage patterns by BGS Staff, which, if the Strong Room had not been used, it would not have been influenced by external changes in temperature.

Comparing the annual data with 2004, a similar pattern emerges, where weekly variations still occur in 2004, but during autumn – winter. All areas still show an increase above the recommended 16-19C, but the raise in internal temperature is not noticeable during summer 2004. This could be due to staff members and visitors, opening windows during the summer to allow for a more comfortable working environment, unfortunately allowing the warm air from outside to migrate into the building.

Humidity readings during 2005 are similar, yet different, for specific locations within the NGRC. The two monitors in the records room almost mirror each other, with readings being slightly higher in the aisle rather than the cardboard storage box, which is slightly buffered from the effects of humidity change. The humidity values for these monitors are below the minimum recommendation of 45%RH, down to 30% RH during the winter and spring. Whilst during the summer, the humidity often falls within the 45-60% RH parameters. The data from the strong room also shows similarities through the year, but with values often between 5-15% higher. It appears that all locations are being affected by humidity changes; this coincides with the hotter humid summers, and the colder external conditions, together with the use of the central heating within the building. The only difference is during November and December, where the humidity within the records room falls below the 45% guideline, whilst the strong room humidity remains reasonably constant. This shows the effect central heating has on an area, or in the case of the strong room, where buffering by being closed off for much of the days, shows it is not so influenced by changes in the heating. Additionally, the construction and location of the strong room is buffering its contents from the lower humidity experienced within records room and surrounding offices.

Generally, data from 2004 is similar to that of 2005, with the aisles in the records room showing slightly higher humidity readings than the monitor within the cardboard box, and the strong room displaying values 5-11% higher than the aisles. Periods during the winter have produced lower readings for longer in 2005 compared to 2004. Therefore during the summer months, the amount of time within the recommended parameters is less.

Figures 27 & 28 display temperature and humidity in the form of histograms for all areas within the NGRC. It can be seen that the temperature for all the locations within the NGRC fall outside the 16-19C for at least 99% of the time. The overview of the humidity readings is however more promising. Under the new parameters (45-60% RH), it can be seen that the humidity in the strong room is within range for 72% of the time, compared to 26% for the monitors within the records room. The Strong Room is below the recommended value of 45% RH for 27% of the time, whilst the Records room is below these guidelines for 72% of the time. No readings were recorded above 60% RH.

Comparisons for the percentage of time within the ranges for both 2004 & 2005 are shown in figure 29. It can be seen with previous line graphs that the amount of time within the temperature ranges for both years is extremely low, only around 2% or less. The humidity readings within the records room are on average 27% of the time within range for 2005, where as during 2004 this figure was 29%. Whereas the strong room with its enclosed environment and improved buffering properties, has shown a 23% decrease in humidity compared to 2004.

Even though there has been a decrease in values from last year, it must be remembered that 2004 only contains partial data. This does not take into account readings prior to June 2004, where internal readings are generally lower towards the beginning of the year. If values had been recorded, it is probable that the percentage of time during 2004 would have been similar or lower than 2005.

2.6.1.2 Monitoring within the NGRC Summary

Like 2004, all locations within the NGRC follow similar trends throughout the year. The temperature readings show little or no buffering effect provided for material by the cardboard storage boxes when comparing this to the data for the monitor situated in an aisle. The strong room shows slightly higher, less fluctuating temperature readings than the records room. This shows that the strong room does buffer the environment to some extent.

It appears that weather variations are having an effect on the internal conditions to some degree. All areas are outside the recommended temperature ranges, whilst the strong room is showing a more stable environment in terms of humidity compared to the records room, even though all areas are within the recommended humidity range for between 26-74% of the time depending on location.

Actions need to be taken to improve the conditions within the NGRC, by generally lowering the temperature and increasing the humidity, especially during the winter months. Such a task could prove to be difficult, due to the numerous factors involved, such as working practices and comfortable working conditions, fabric of the building and the ability to minimise the effects of external climatic variations.

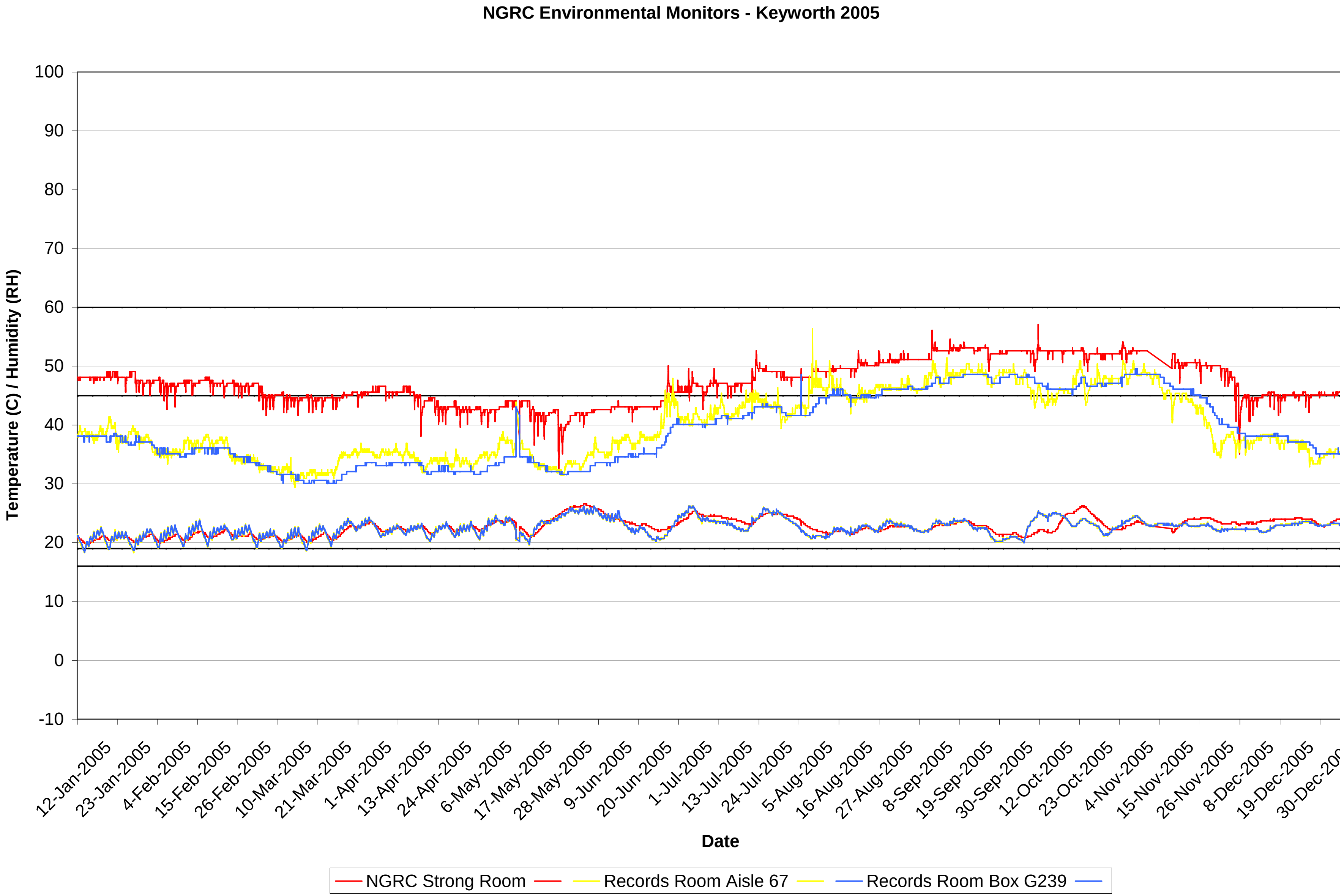

Figure 25: Temperature and humidity values within the NGRC 2005

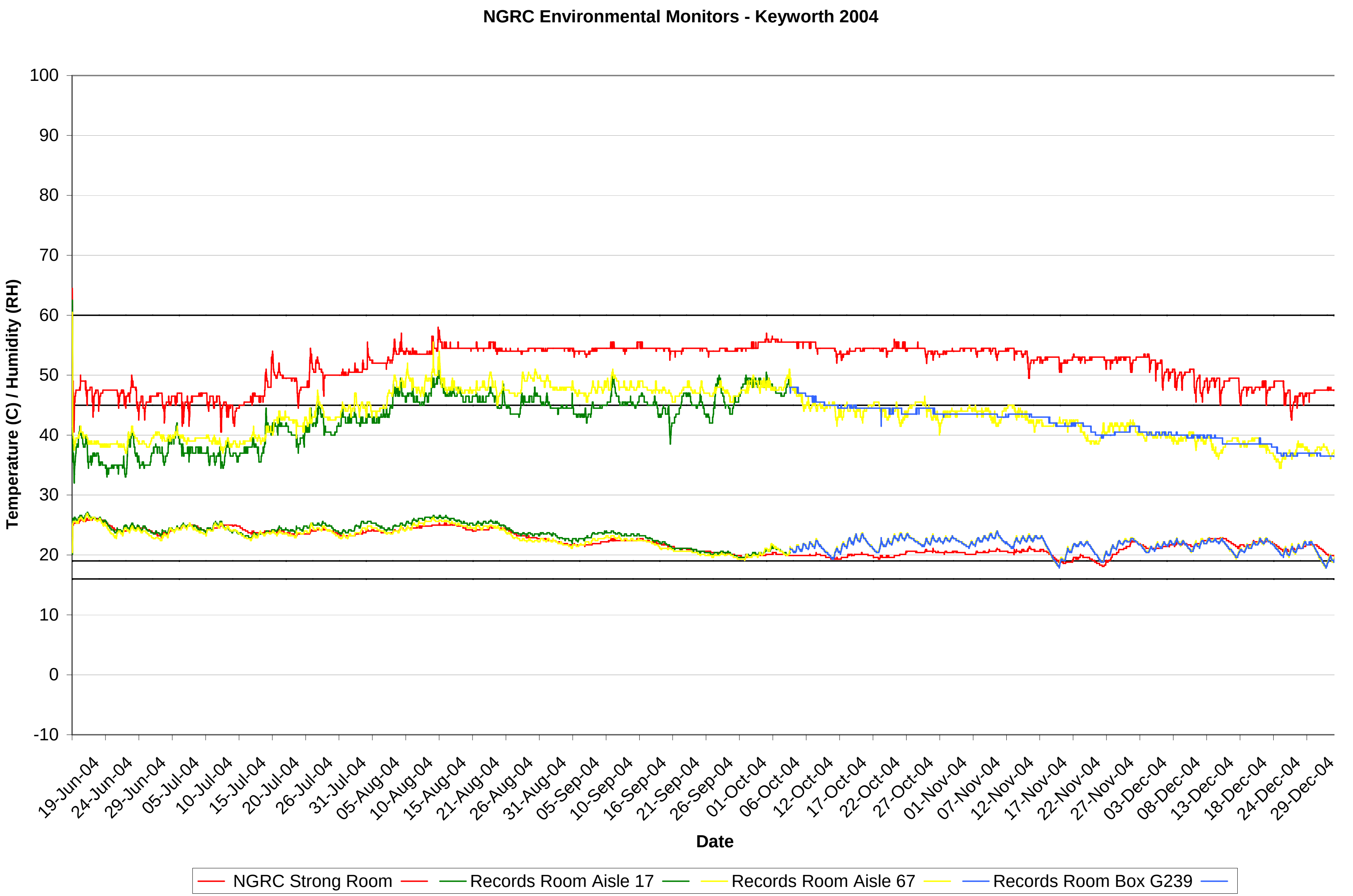

Figure 26: Temperature and humidity values within the NGRC 2004

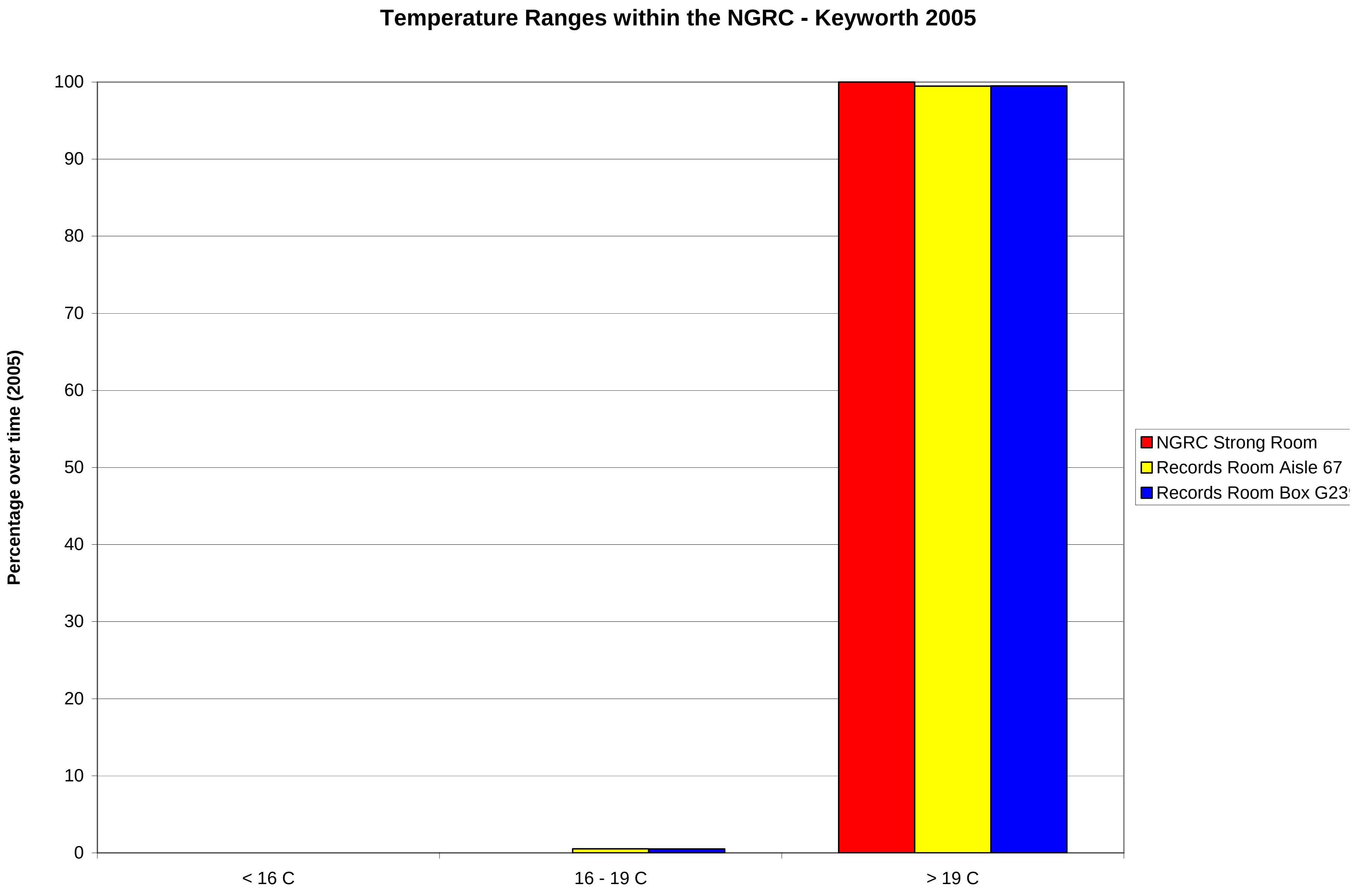

Figure 27: Histogram: Temperature ranges within the NGRC 2005

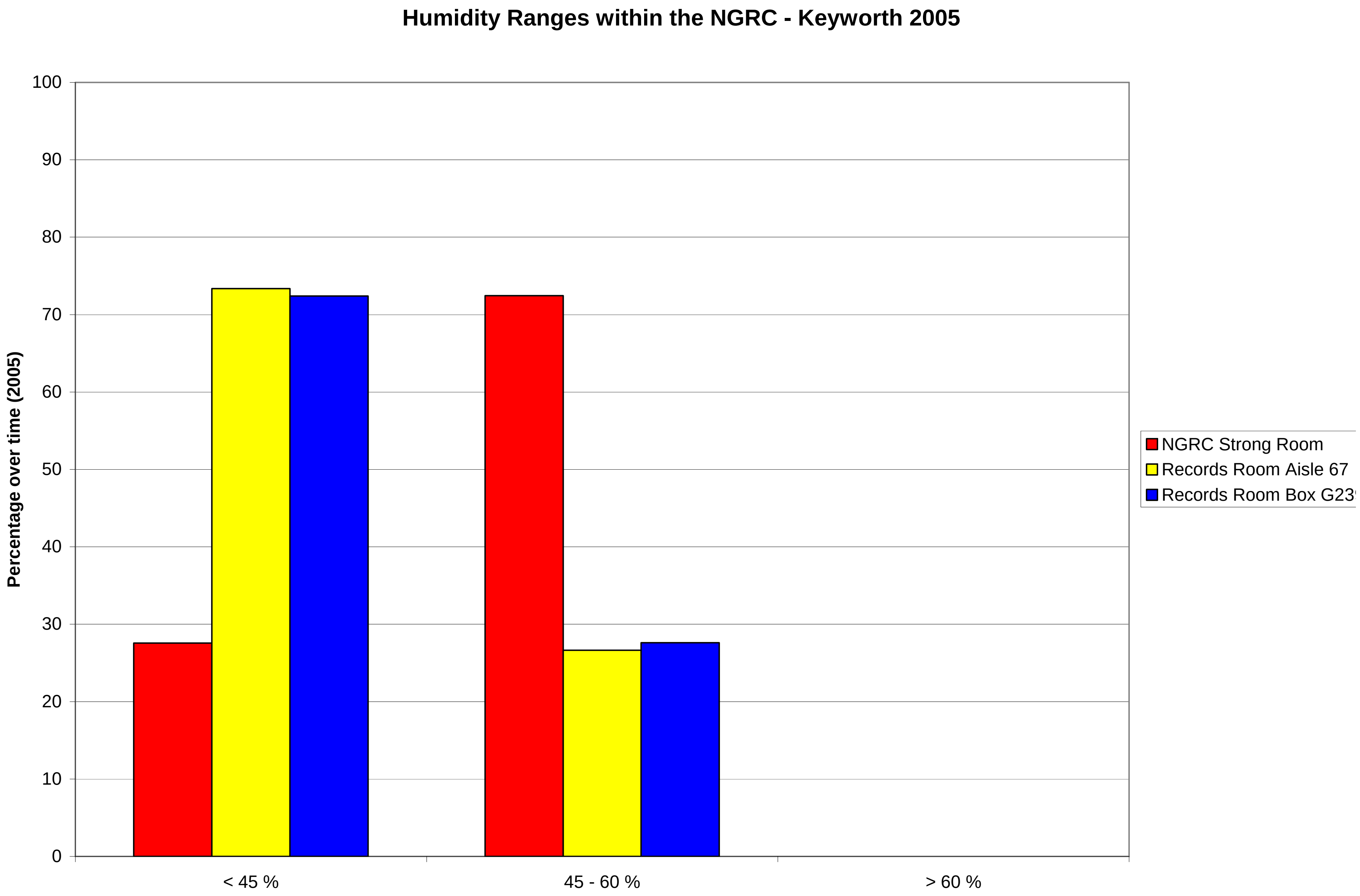

Figure 28: Histogram: Humidity ranges within the NGRC 2005

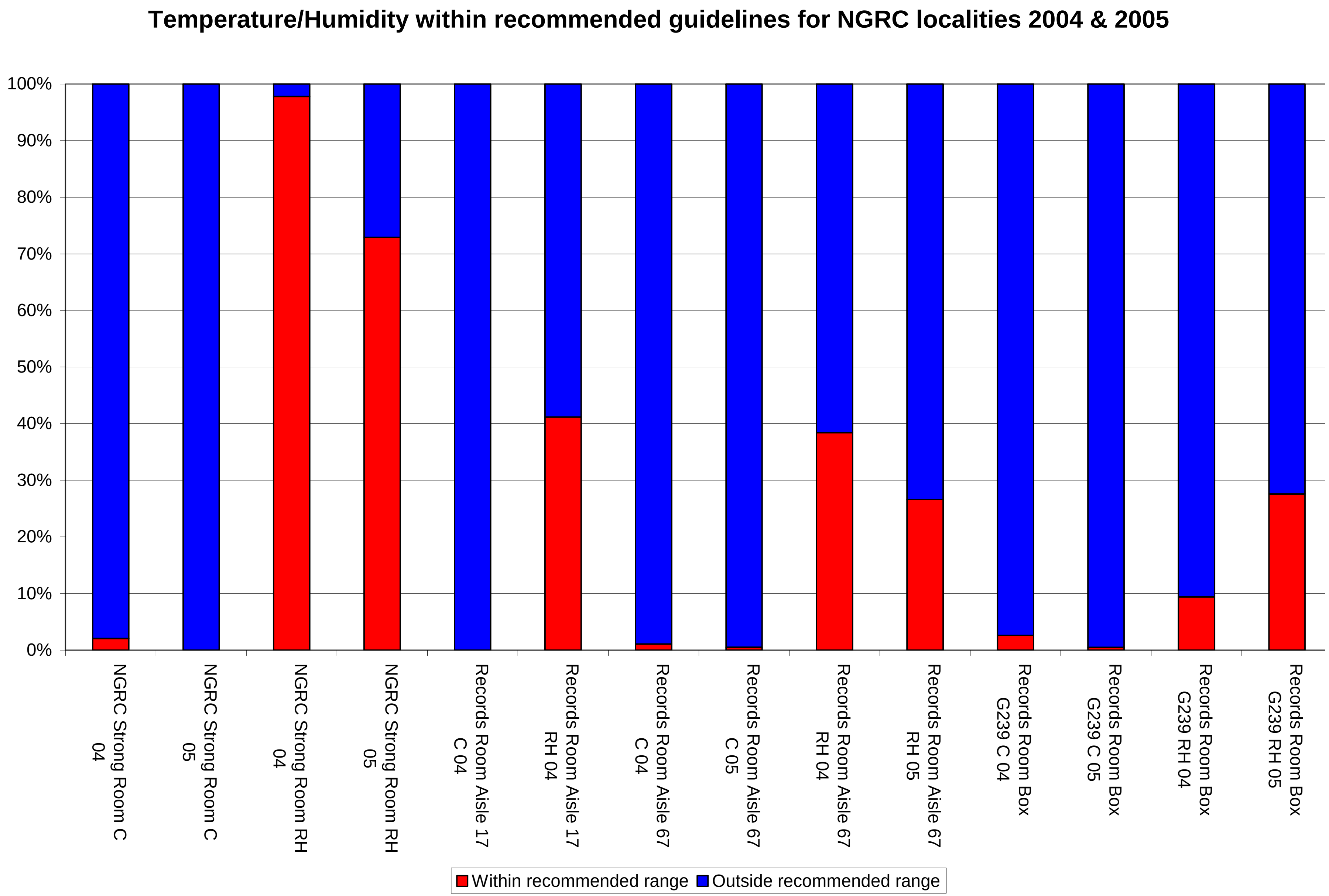

Figure 29: Temperature / Humidity within guidelines for the NGRC 2004-2005

2.7 MONITORING WITHIN THE LIBRARY STRONG ROOM 2004

Since May 2005, a new air conditioning system has been installed within the Library strong room to comply with the British Standard BS 5454:2000, which recommends for the preservation of archival documents the temperature should between 16-19°C, whilst the Relative Humidity should be between 45-60%.

2.7.1.1 MONITORING WITHIN THE LIBRARY STRONG ROOM RESULTS

A graph displaying the results for the library strong room is shown in figure 30.

Readings through the year show that the temperature within the strong room is situated within or close to the 16-19C parameters. Up until mid March the temperature fluctuates gradually. After that period there is a noticeable rise, this coincides with an increase in external temperatures, possibly via the ceiling vents in the old air conditioning system. From the beginning of May, when the new air-conditioning system became operational, a visible change in the style of readings was recorded, which produces readings from 15 – 18C. There is missing data from mid July to mid August, due to the monitor being pushed off a shelf and incorrectly put back together, whilst material was being organised. This caused a loss of data. It can be seen that after the event the readings are similar to those prior to the accident. From mid November there is another rise in temperature, up to 18-19C. This increase cannot be explained conclusively, but could be due to a change in the temperature regulator within the air conditioning system, or warmer air being drawn in from the surrounding rooms to the library strong room, during periods of occupancy.

The humidity values unfortunately do not meet the 45-60% parameters throughout the year. During the spring and early summer the reading are just below the 45% mark, whilst during the summer the readings are constantly fluctuating above the 60% parameter. The period that is most suitable occurs during May-June and late October. From the beginning of November, there is a decrease in humidity, which then fluctuates at a lower level. No true explanation for this can given, except that it coincides with other areas across the site, where there is an increase in internal temperatures, which in turn, causes the humidity to drop due to the air being dried out.

A comparison can be made between 2004 & 2005 using figures 30 & 31, where 2 months of data was available 2004. During this period the temperature is constantly at 19C, compared to 2004 where readings where between the 16-19C ranges. However during 2004, when the old non-functioning air conditioning system was in place, the humidity was within the 45-60% guidelines for 100% of the time, however during 2005, this fluctuates below the recommended minimum.

Figures 32 & 33 show temperature and humidity histograms for the Library strong room. It can be seen that the strong room is within the temperature range for 47%, whilst the humidity within this area is within the recommended parameters for 39% of the time. Values below the recommended temperature and humidity ranges account for 28% and 39% respectively, whilst readings above these ranges are 23% for temperature and 21% for humidity. No comparisons between this year and 2004 have been made, due to the lack of data collected during 2004, (2 months), as this would show inaccurate comparisons between both years.

2.7.1.2 Monitoring within the Library Strong Room Summary

On examining the data, we can see major variations in temperature and humidity readings throughout the year. There are periods from the middle of November, where sudden decreases in humidity occur that cannot be explained. After looking at the raw data in detail, the percentage of time within the temperature range has decreased from 67% to 36% after the installation, whilst the humidity has seen an increase from 32% to 42% with the system operational. With the installation of the new air conditioning system, issues still need to be rectified, such as high humidity readings and reducing any sudden changes within the strong room. It is imperative that the monitoring of this situation together with the collaboration of Facilities Management to rectify these problems continues.

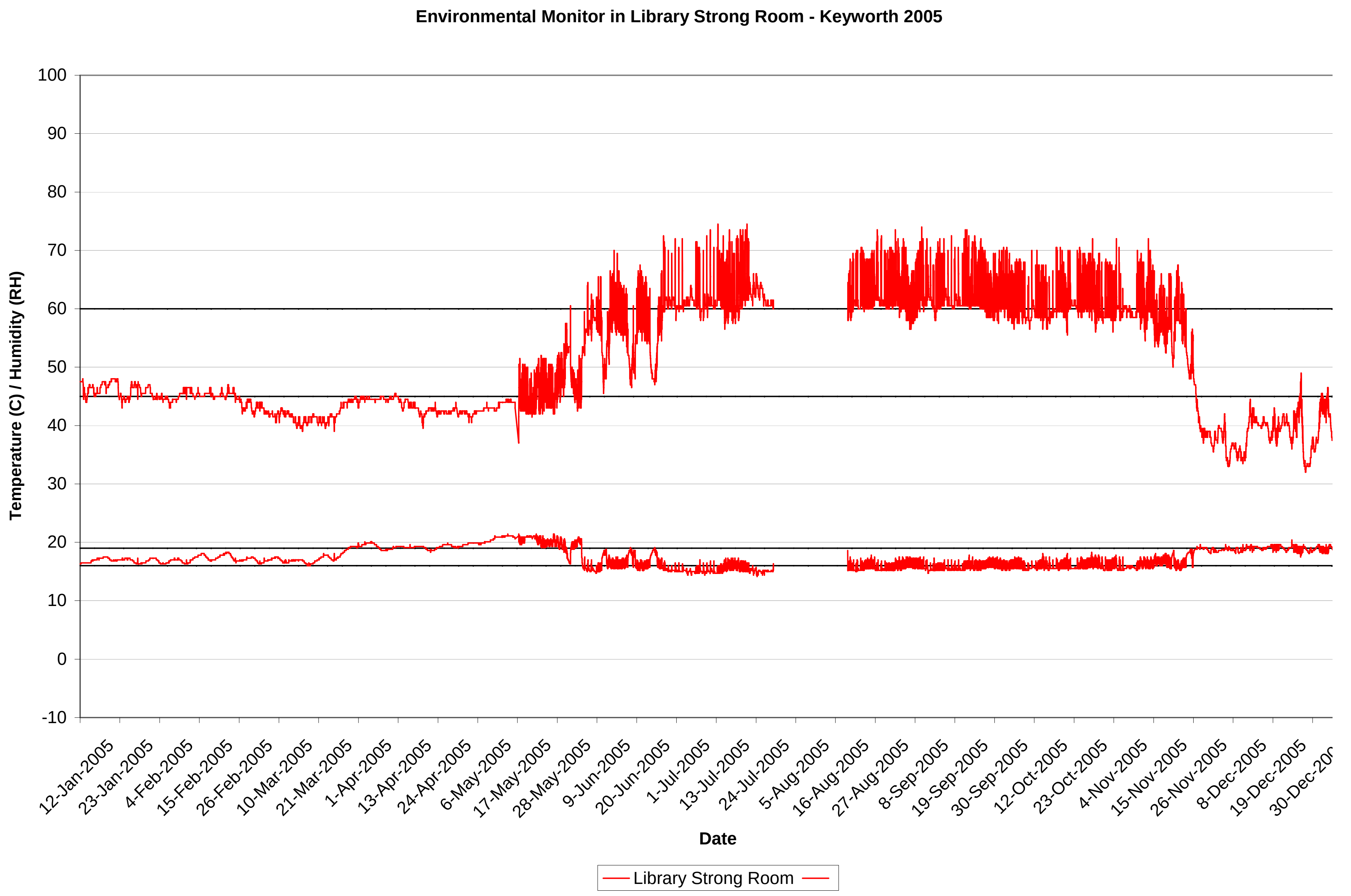

Figure 30: Temperature and humidity values within the library strong room 2005

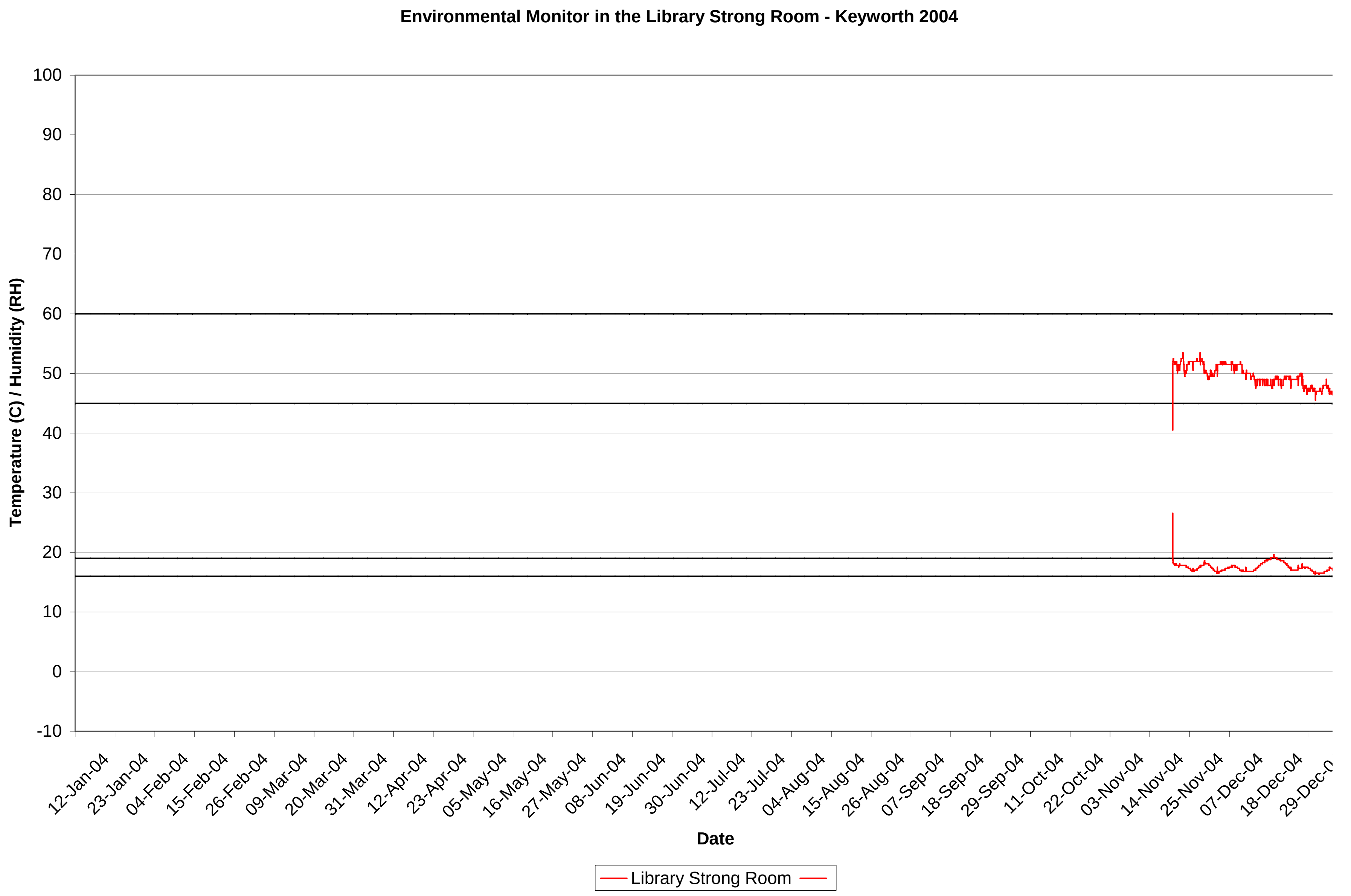

Figure 31: Temperature and humidity values within the library strong room 2004

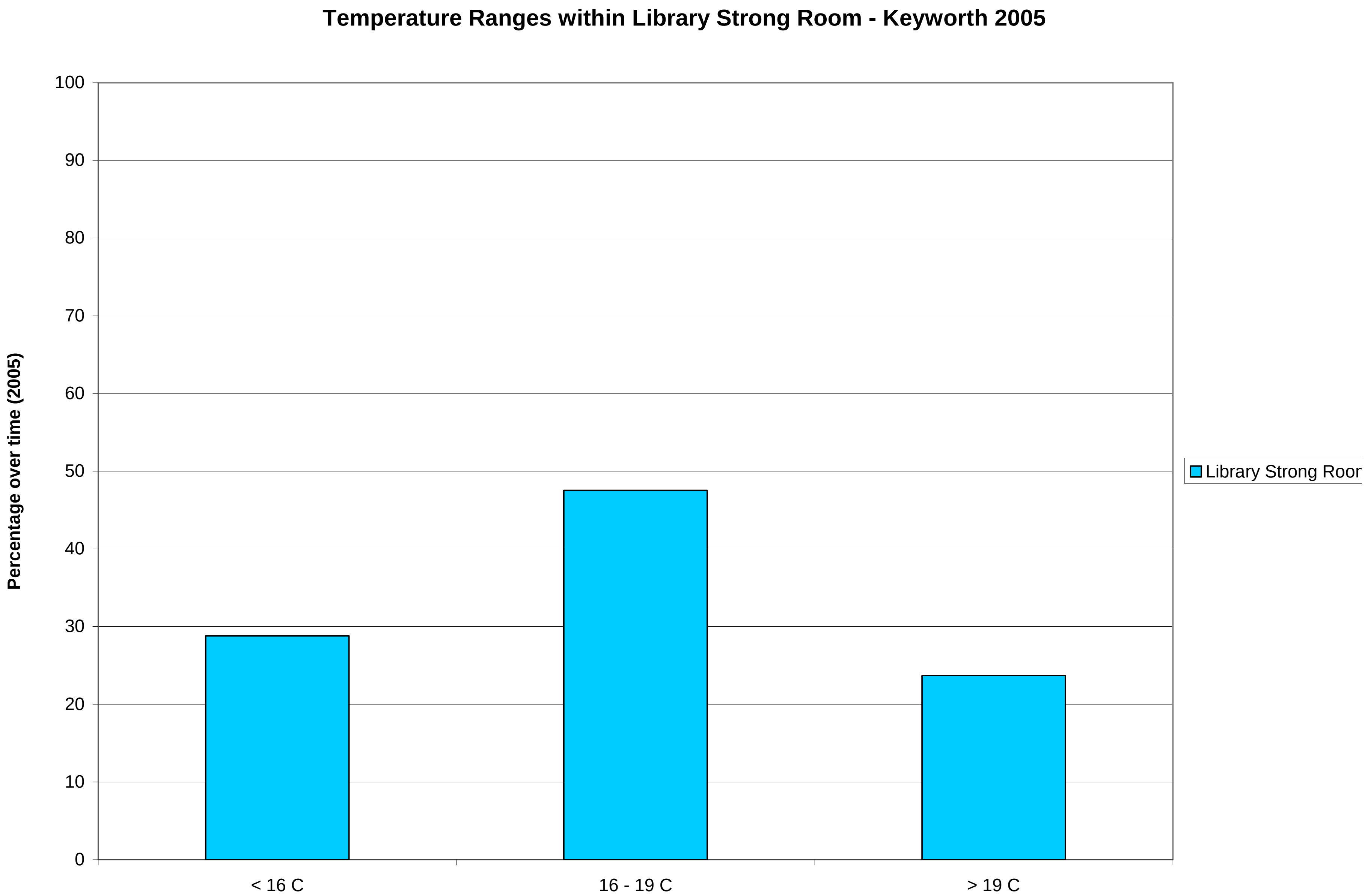

Figure 32: Histogram: Temperature ranges within the library strong room 2005

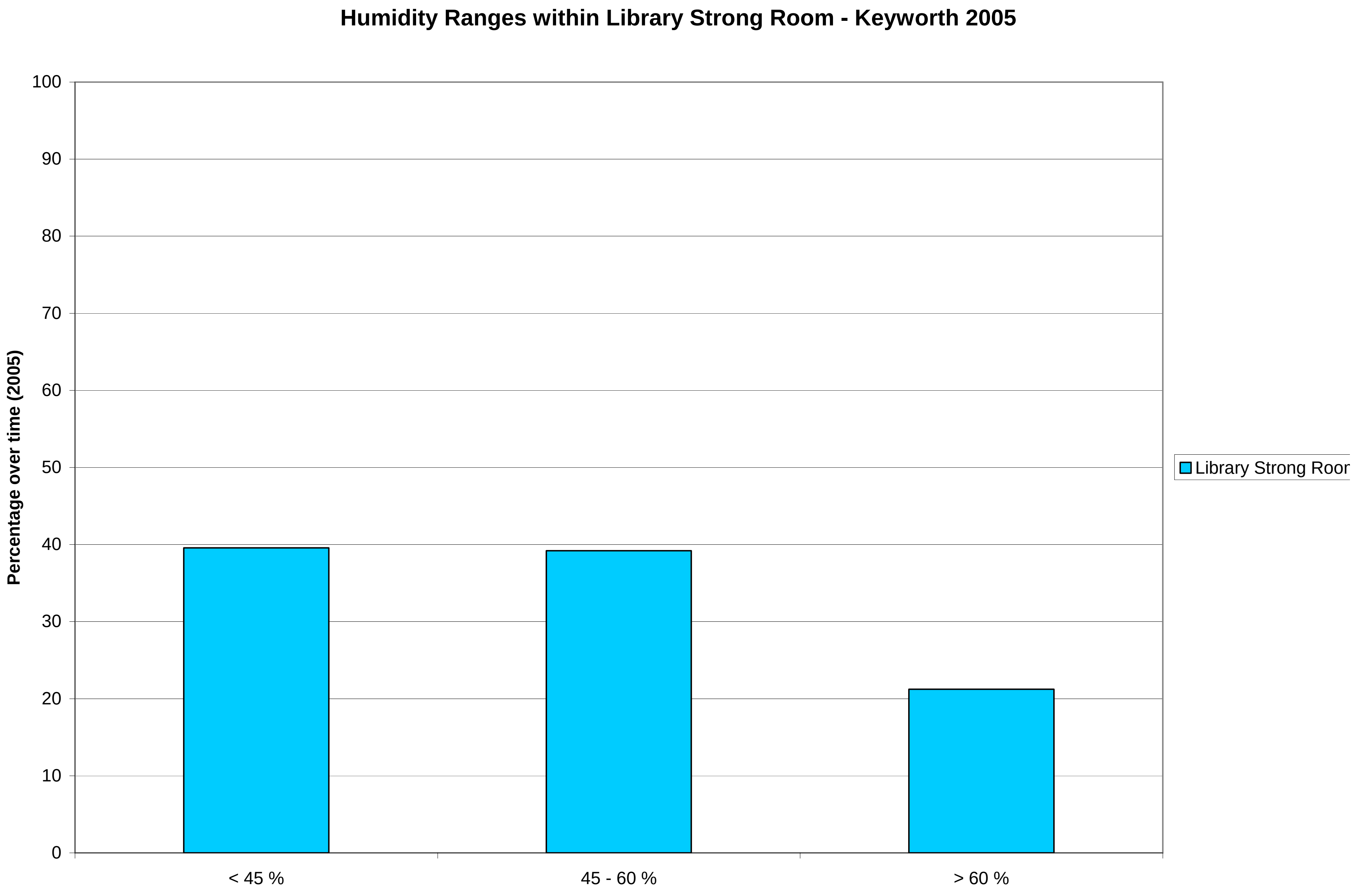

Figure 33: Histogram: Humidity ranges within the library strong room 2005

2.8 2004 RECOMMENDATIONS ACHIVED DURING 2005 FOR KEYWORTH

Based on last years report *Shepherd & Tulloch, 2005*, the following recommendations have been achieved during 2005.

2.8.1 General monitoring

Monitoring has continued throughout the year for all existing main areas. Certain zones that had partial data during 2004, such as the Library strong room, sub-fossil bone and Laboratory, now have full data for the year to be used for comparative purposes.

New monitors have been positioned where continual data was not previously available; this includes a mahogany drawer on the first floor of the Museum, and within the weather station. Calibration of all monitors continues on an annual basis.

A deep clean of the museum cabinets and drawers has commenced during late 2005. This will improve the appearance of the material stored within, and will provide an opportunity for problematic areas to be bought to the attention of Museum staff and the Conservator. The removal of dust provides a better working environment for staff and visitors and should assist in the preservation of the specimens.

2.8.2 Core store

Compared to 2004, all areas within the core store now have permanently positioned monitors providing annual data.

A trial experiment placing a beaker of water within the Conservation laboratory during a period of low humidity has proved successful at helping to increase the humidity within that area.

2.8.3 Museum

Defects in the fabric of the building within the museum were bought to the attention of Facilities Management and have been rectified, e.g. re-plastering and painting was carried out to repair damage due to a previous leak in the roof.

The Conservator on a regular basis carries out a systematic condition surveys to assess the condition of the collections.

An additional monitor has been positioned within a museum drawer on the first floor of the museum, to provide comparative readings between that and the general museum environment.

2.8.4 NGRC

Continual monitoring throughout 2005, has allowed annual data to be collected along an aisle and in a storage box within the records room, and within the strong room.

Data is sent to the relevant area manager on a weekly basis, to allow the continual assessment of the information collected.

2.8.5 Library Strong Room

During 2005, full data has been provided by continually monitoring the environment within the strong room.

The installation of an air conditioning system within the strong room has been undertaken, aiming to comply with The British Standard BS5454:2000.

Weekly data from the monologger within the strong room is sent to Library staff for comparison with the British Standard.

2.8.6 Miscellaneous Areas

An additional monitor has been placed within the Stevenson Screen, to provide external temperature and humidity data on a regular basis.

Previous implemented recommendations on usage patterns within storage areas are continually being honoured. These include the closure of museum cabinet doors and window blinds, and the shutter doors within the core store whenever possible.

2.9 RECOMMENDATIONS FOR KEYWORTH 2005

2.9.1 General Monitoring

- It is essential that monitoring continues for all the areas reported on within 2005, so that we can continually assess the effects that temperature and humidity are having on the collections.
- Data should be sent to the relevant area manager on a weekly basis, to allow them to make an assessment of the information collected and to inform Facilities Management of any necessary changes they think may be required.
- Calibration of the monitors should continue on a regular basis throughout the year, where new monitors can be used as benchmarks during the calibration period.
- When additional funding becomes available new monitors should be purchased. This would enable us to collect data from new locations and any problematic areas, which may need investigating further, via a mini project.

2.9.2 Core Store Areas

- Additional experiments to increase the humidity within the laboratory should continue especially during periods of known low humidity, such as spring and late autumn.
- To use the ceiling fans and air-blown system more effectively during the summer months, with the aim of reducing the high temperatures recorded on the top floor of the tray store.

2.9.3 Museum Areas

- To increase the humidity in the vicinity of the sub-fossil bone specimens on the ground floor of the museum. Trials similar to those carried out in the conservation laboratory should be put into practice to prevent periods of low humidity occurring.
- Additional monitors when available; should be used to record the conditions within the wall cabinets containing the majority of the sub-fossil bone material. This would allow comparisons between the storage areas to be made and thus ascertain their suitability for storing this type of material.

2.9.4 NGRC Areas

- The use of temporary portable humidifiers to increase the humidity during colder periods, even within the strong room, until a permanent environmental control system is installed within the NGRC would be beneficial.
- To keep all window blinds shut where possible to reduce the effects of solar gain within the records room, until suitable replacement blinds are installed.
- Thermostatic controls on the current heating system should be used to lower temperatures within the records room, as they are presently too high.
- To examine the possibility of removing some radiators from the records room. This should assist in reducing temperatures throughout the year.

2.9.5 Library Strong Room

- Continual monitoring of the strong room is essential to assess the effectiveness of the new air conditioning system, thus allowing any adjustments to be made in order to improve the conditions within the strong room.

3 Monitoring at Murchison House

Ten Digitron loggers are used to gather internal temperature and humidity data in Murchison House, three in the Palaeontological storeroom, three in the Petrological store and three others, including a 'mobile unit', in the Archive Store housing non-geological material, mainly paper records and reports, see Figures 34 & 35.

An additional system, located on the northwest roof of Murchison House, is used to capture weather statistics. This unit monitors wind speed & direction, temperature, humidity and rainfall. These data are uploaded to a networked computer and can be interrogated in real-time or the data downloaded to a local pc in daily files.

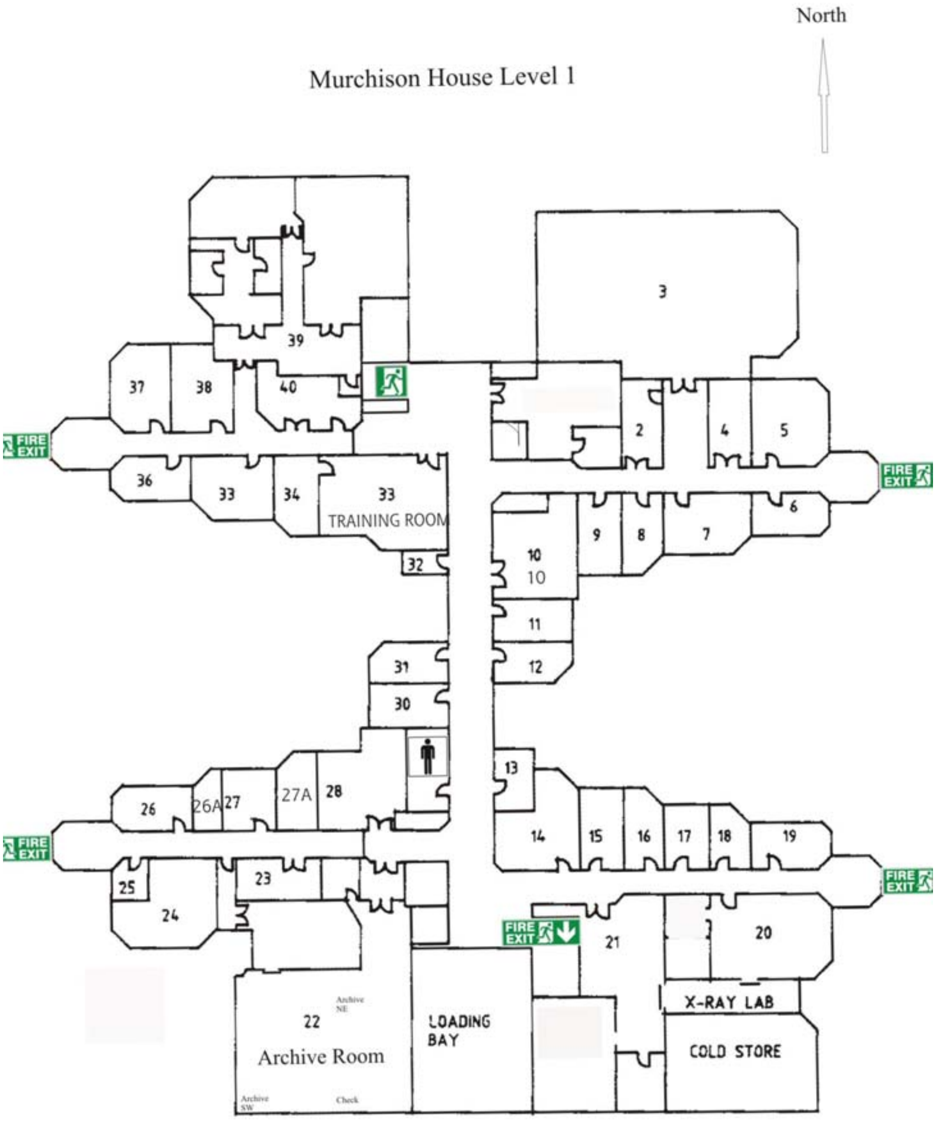

Figure 34: Location of Murchison House loggers: Level 1, Archive Room

The Archive Store has only been monitored for six months, from June 2005. This is a newly refurbished store designed to house working documents including reports and records. It is fully air-conditioned, the temperature and humidity are controlled by a computerised system designed to maintain the environment at the levels set in BS5454: 2000.

The logger housed in the Entrance display cabinet was moved to this store to verify the data from the two loggers positioned in the Archive as their history was unknown and the initial data from these was unexpected.

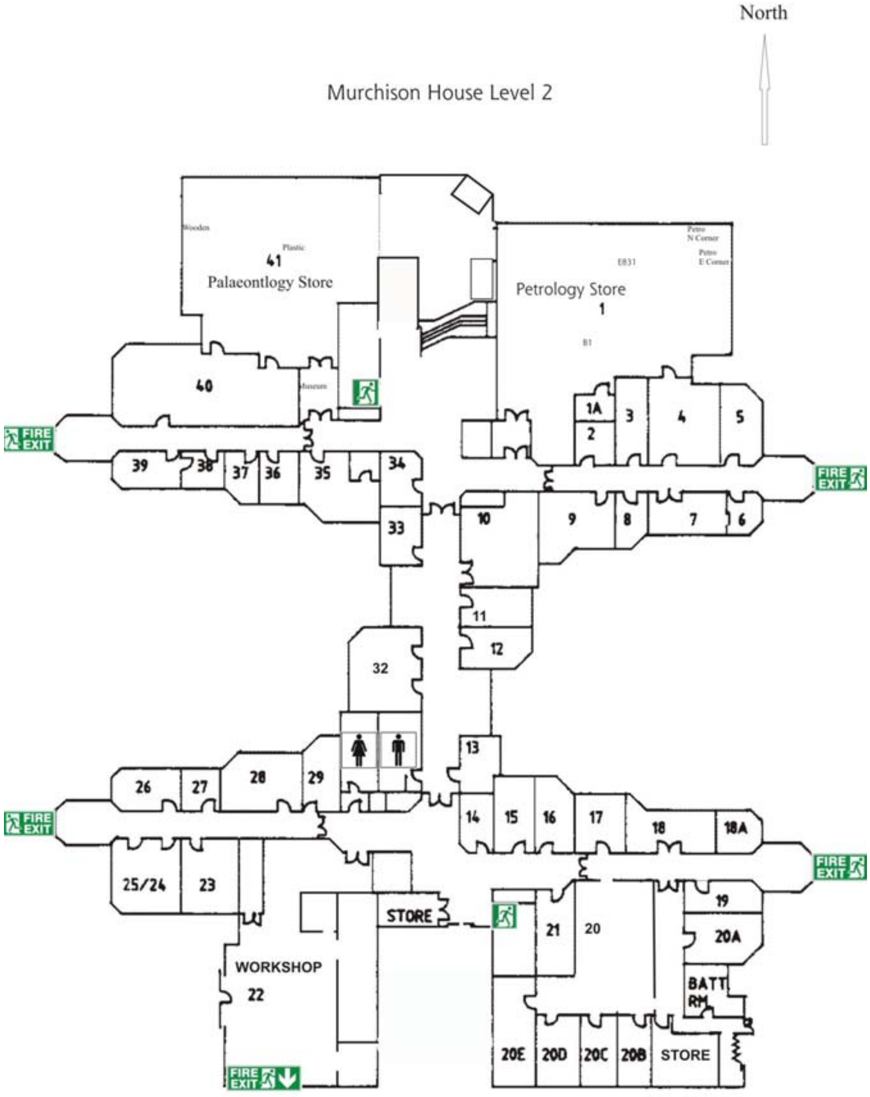

Figure 35: Location of Murchison House loggers: Level 2

In the Palaeontological area there is one logger in a Museum specimens cabinet and one each in a wooden tray and a plastic tray, both covered, in the general store.

The loggers in the Petrological store are situated in such a way as to show the difference between the environment in a closed plastic tray and the environment in the open store. Two monitor an area of particular concern and are also in the open.

Internal data is download every Tuesday (to avoid Monday holidays) at approximately 10am. By downloading on the same day and time every week errors or sampling artefacts can be easily identified.

Data are saved to logger compact file format, readable only with the propriety software supplied with the instruments, and have the extension lcf. These are the master files.

The files are converted into MSExcel format and imported to an MSAccess database. All data are recorded in GMT and require no alteration from BST

The Excel spreadsheets labelled " MH 30 Minutes 2004.xls" and " MH 30 Minutes 2005.xls" contain data for 2004 and 2005 extracted from an MSAccess database in which all data is stored. It is from these files that the annual graphs are produced.

Data from the Weather Station are uploaded automatically on a computer and downloaded in daily ASCII files with extensions identifying the content (.MHU, .MTA, .MWD, .MWS, .PP designating Murchison House Humidity, Temperature, Wind Direction, Wind Speed & Rainfall resp.).

The Excel spreadsheet labelled “Met data 2005.xls” contains all available Weather Station data for 2005 in 30-minute intervals. It is from this file that the external data graph is produced.

3.1 CALIBRATION

When purchased, the loggers are guaranteed for accuracy of +/-0.3^{o}C with an average resolution of +/-0.3^{o}C. The units are placed in the same specimen tray for at least 24 hours, this allows them to be calibrated to the one unit, providing better data for comparison. During 2005 the loggers were calibrated in this way three times: once each in February and June and again in August to include the loggers installed in the Archive Room.

3.1.1 Calibration Method

The loggers were placed in an empty plastic specimen tray overnight for a period of 24-hours. The calibration is undertaken partway through a weekly monitoring period to allow any changes in readings to be more easily determined. At the end of the 24 hour period the loggers are returned to their usual locations and the data downloaded and graphed at the normal time the following Tuesday.

It is recognised that this may not be the most accurate method of calibration, however, new loggers are guaranteed to be very accurate, as discussed above, and the technique chosen is similar to one of the manufacturers own methods.

3.1.2 Calibration Discussion

An excel macro is utilised to calibrate the loggers. Estimations are made to add or subtract values from the data recovered until the traces of all the loggers converged on that of the ‘benchmark’ instrument. The data recovered from the calibration period showed that a few of the temperature values required a little alteration whereas all the humidity values were adjusted by varying amounts.

As can be seen in Table 3 below, the changes in calibration figures are, generally, very small but the associated graphs shows that even these small changes make the data more accurate.

	January		June		August	
Logger	**Temperature**	**Humidity**	**Temperature**	**Humidity**	**Temperature**	**Humidity**
Museum	-0.3	+1.0	Same	+0.7	Same	+1.0
Wooden	Same	+1.5	Same	+1.0	Same	+1.0
Plastic	Base	Base	Base	Base	Base	Base
E831	Same	-2.5	0.2	-2.5	Same	-2.0
B1	-0.3	+1.0	Same	-1.0	Same	+1.0
N Corner	Same	-6.0	Same	-3.0	Same	-2.5
E Corner	Same	-4.5	Same	-4.5	Same	-4.5
Entrance/ Check*	Same	-1.0	Same	-1.0	Same	-0.5
Archive NE					Same	-1.0
Archive SW					Same	-1.0

Table 4: Calibration Values, Edinburgh Digitron Loggers

*Mobile unit

The results obtained from the test periods were sufficient to appease any concerns that there were large-scale problems with the rationale or assumptions behind the test and that the data acquired from the loggers are relatively constant: by calibrating the loggers every 6 months or so the small amount of ‘creep’ is removed before it becomes an issue.

Figures 36, 38 & 40 below illustrate the offset when the loggers were placed in the same location.

The offset is not large, however the results are made more accurate by applying the calibration factor. The benchmark used continues to be the monitor for the Plastic tray, the green line on the graph.

To allow the two sets of data to be more easily compared Figures 36, 38 & 40, the uncalibrated data are provided as a transparency; note the gaps between the lines at the time when they were in the same location. Figures 37, 39 & 41 are the same data that has had the calibration factors applied.

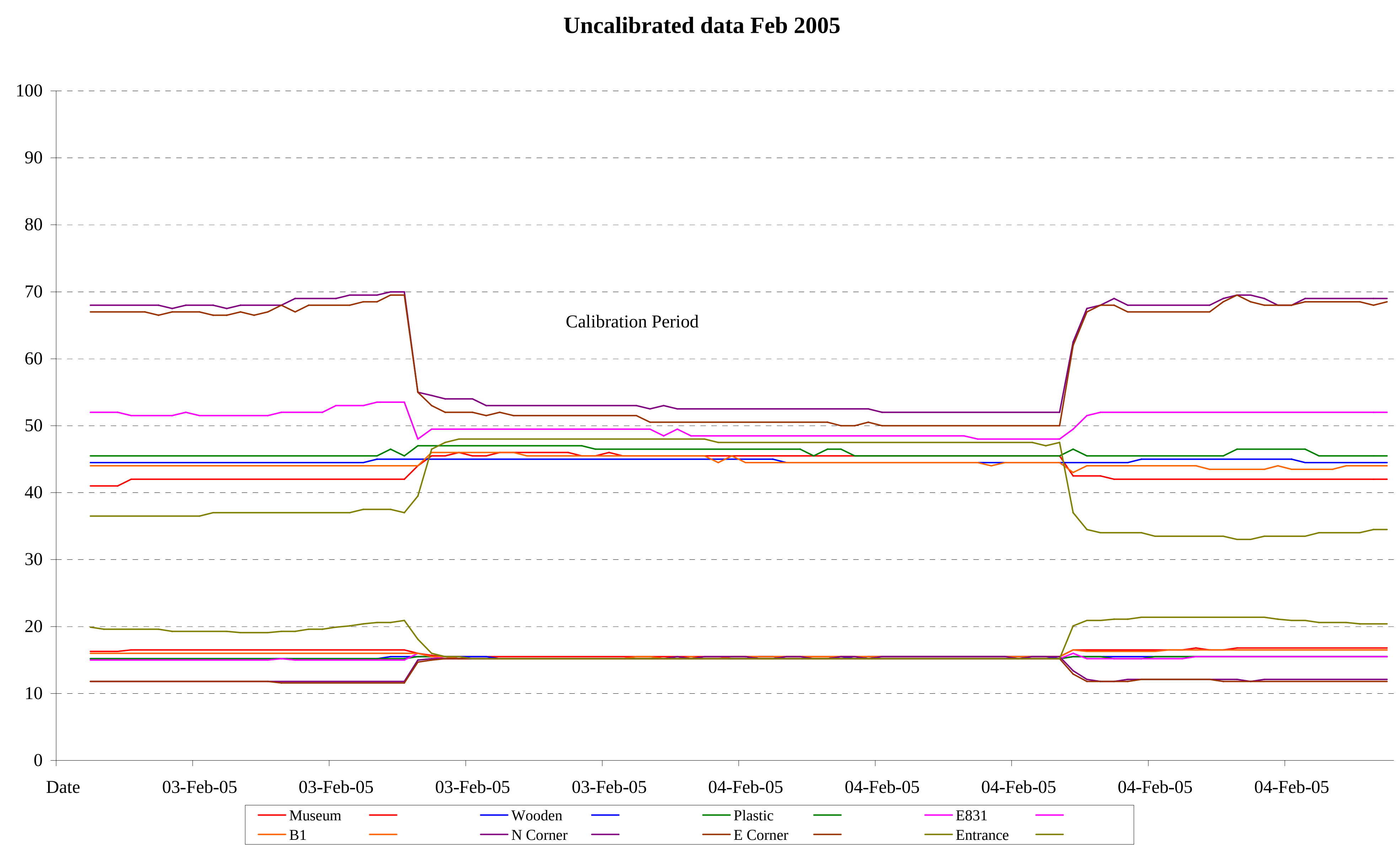

Figure 36: Uncalibrated data – February 2005 test period, Murchison House

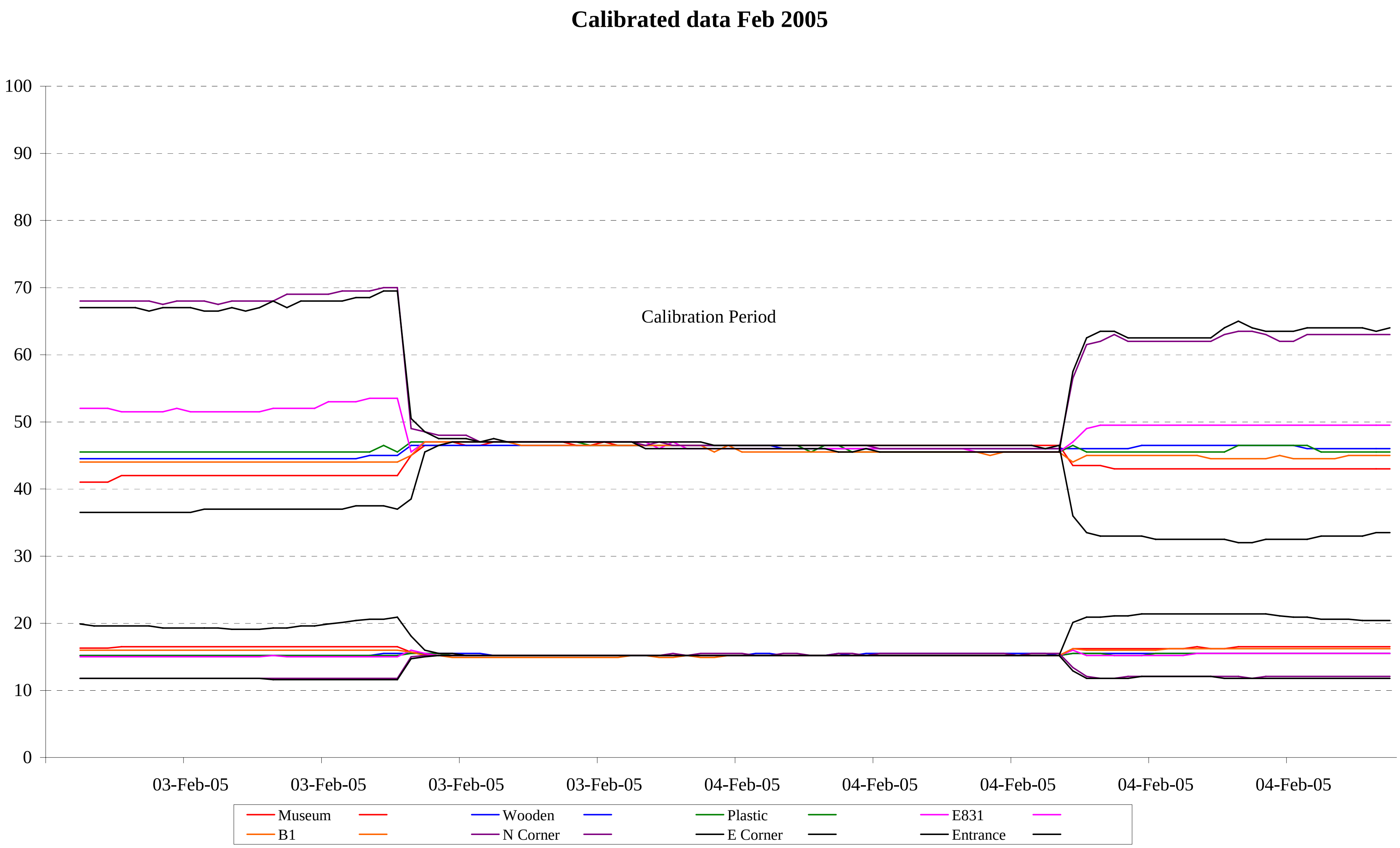

Figure 37: Calibrated data – February 2005 test period, Murchison House

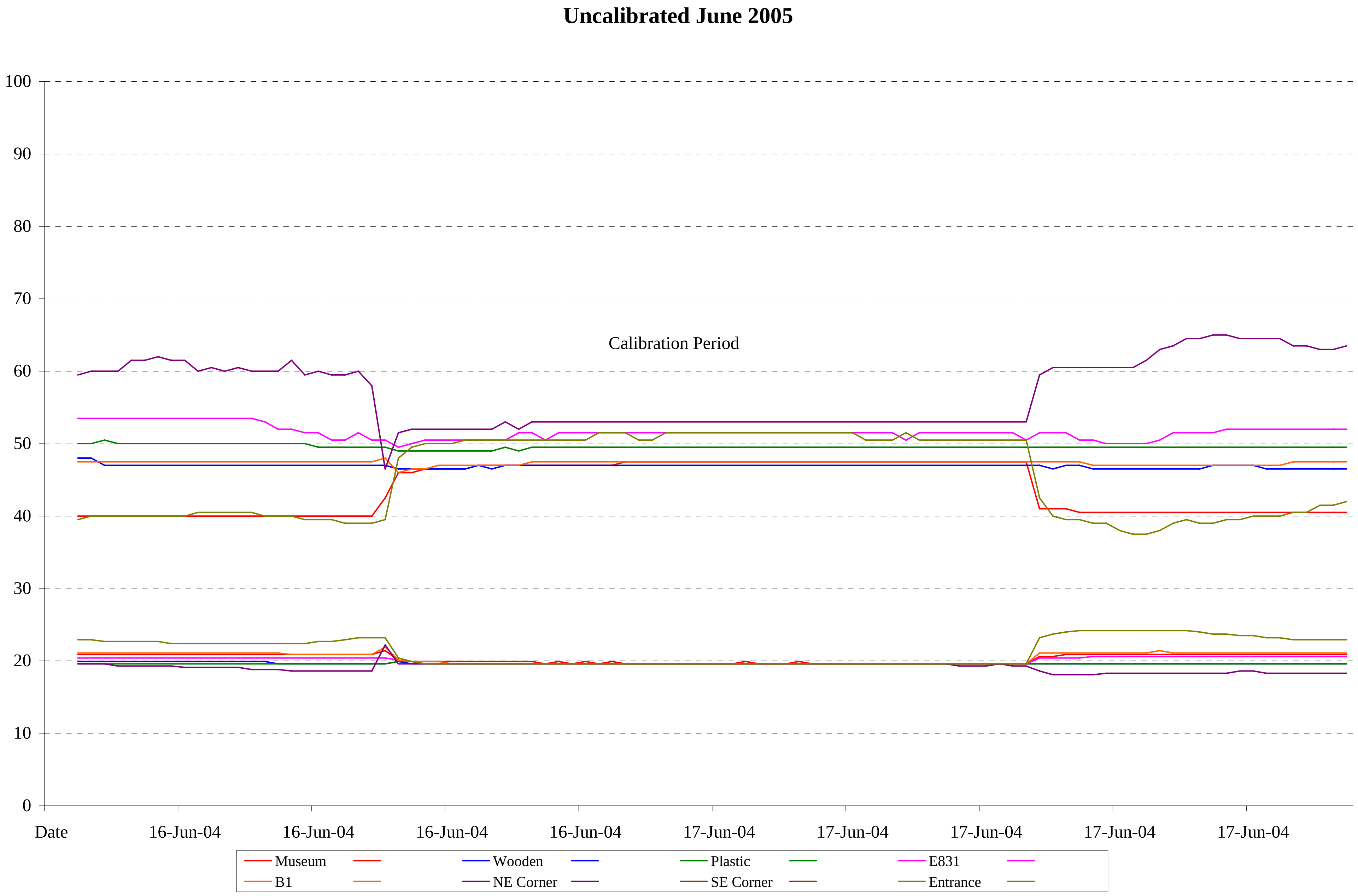

Figure 38: Uncalibrated data – June 2005 test period, Murchison House

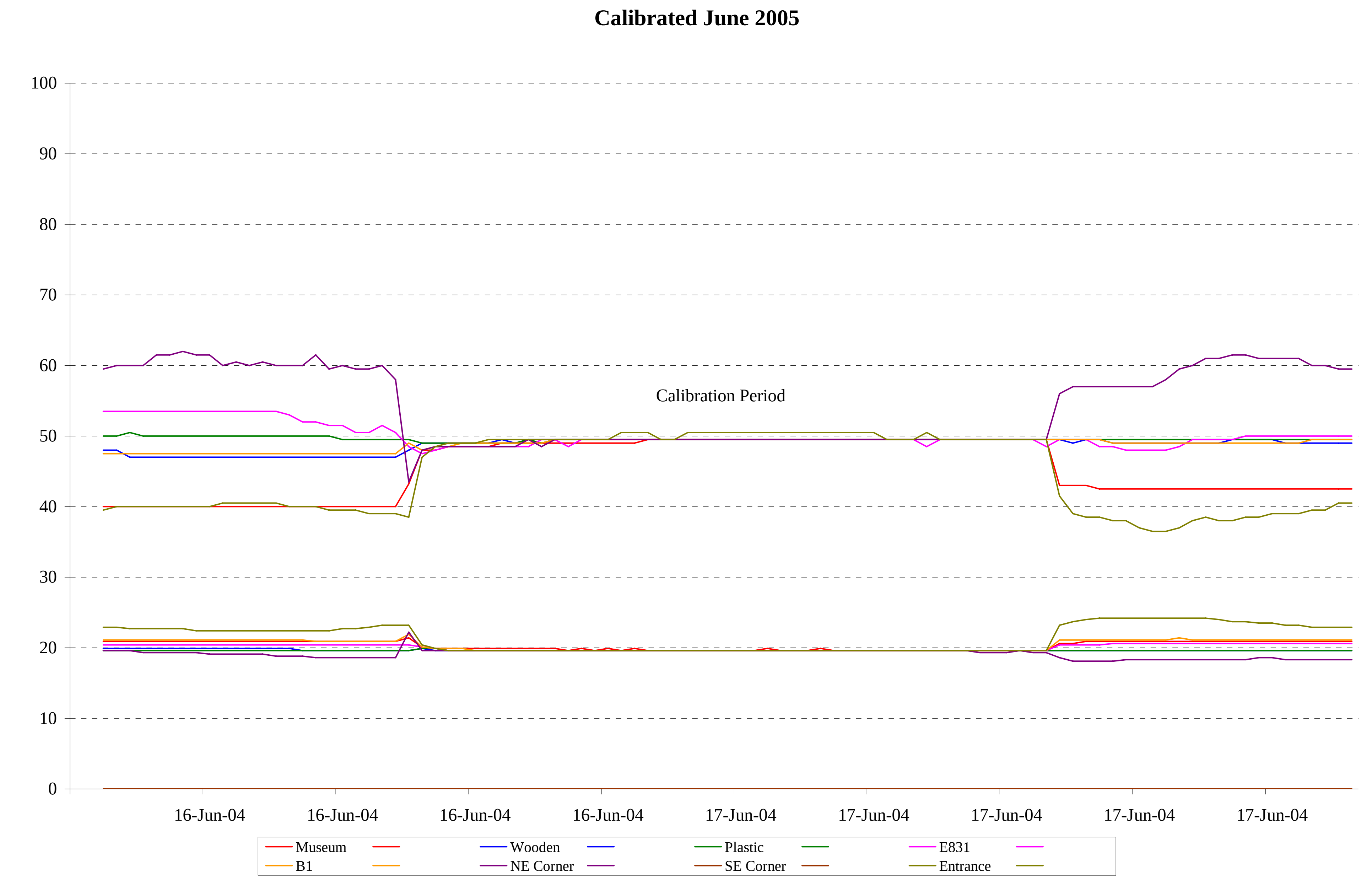

Figure 39: Calibrated data – June 2005 test period, Murchison House

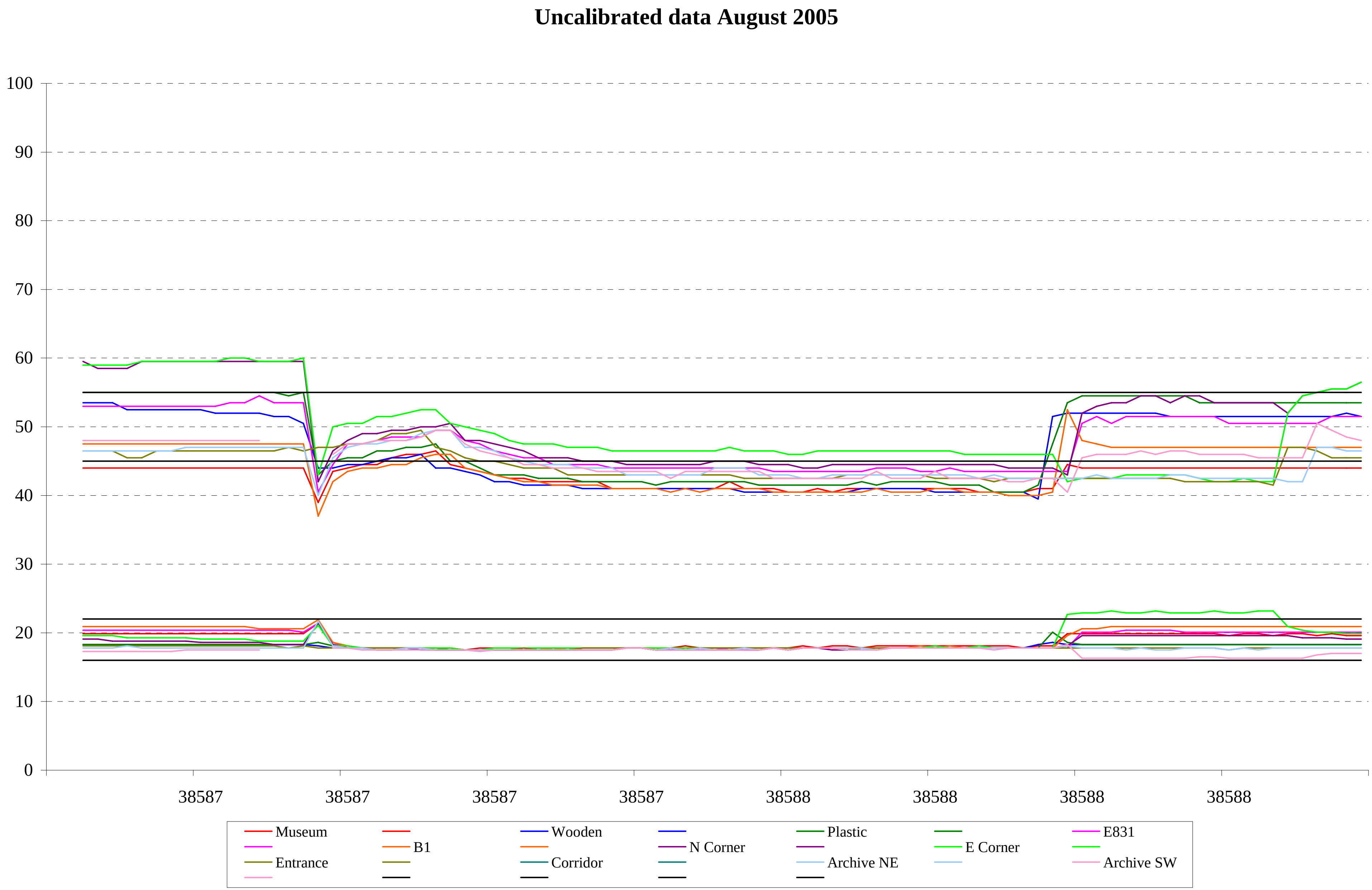

Figure 40: Uncalibrated data – August 2005 test period, Murchison House

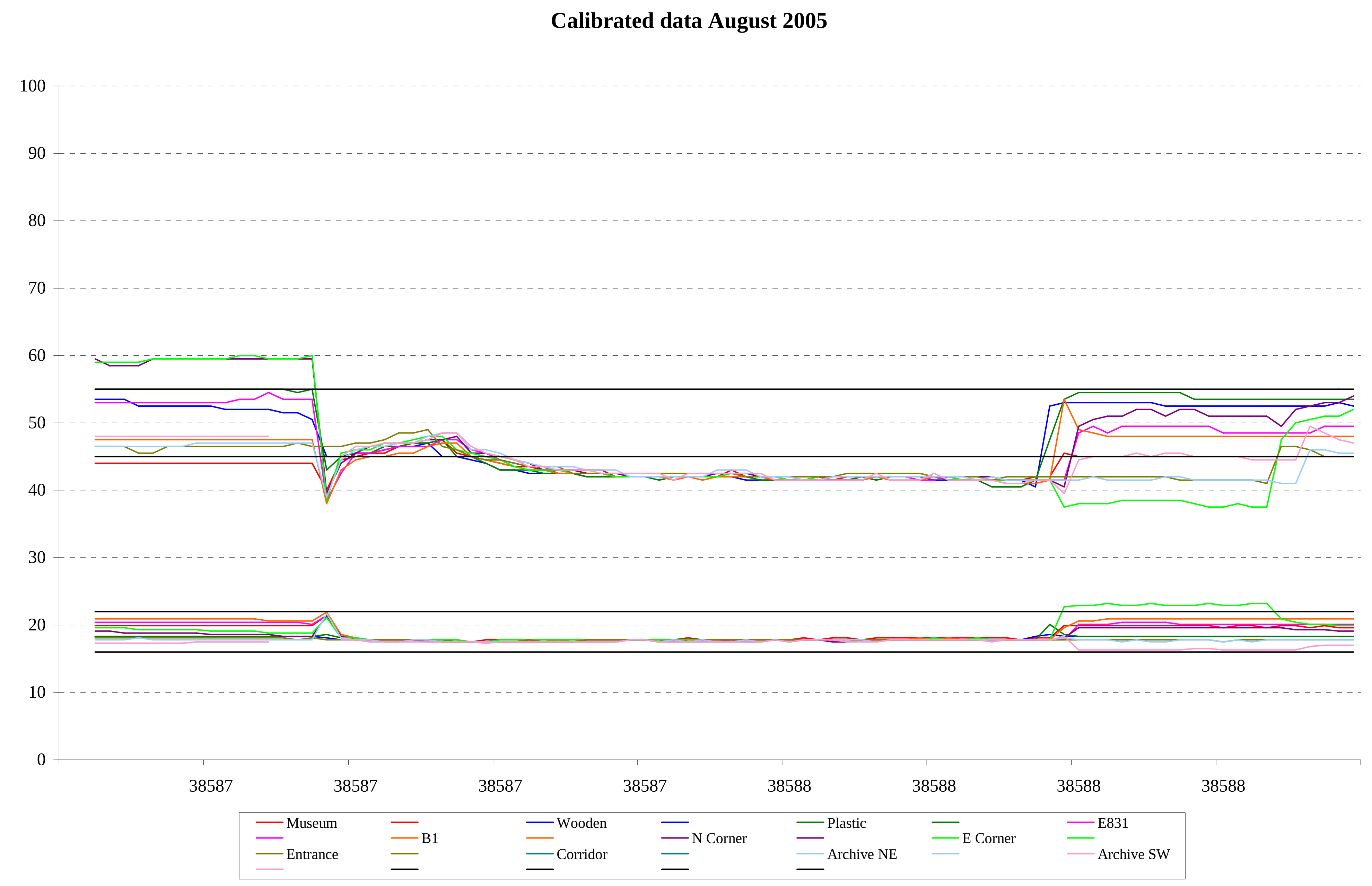

Figure 41: Calibrated data – August 2005 test period, Murchison House

3.2 ANNUAL DATA 2005

A total of ten Digitron loggers are now used to gather temperature and humidity data in Murchison House, three in the Palaeontological storeroom, four in the Petrological store and three others, including a 'mobile unit', in the Archive Store.

An additional system, located on the northwest roof of Murchison House, is used to capture weather statistics. This unit monitors wind speed & direction, temperature, humidity and rainfall. These data are uploaded to a networked computer and can be interrogated in real-time or the data downloaded to a local pc in daily files.

Two loggers in the Palaeontological area are in trays in the general store and the other in a Museum cabinet. The monitors in the Petrology store are also in varied environments; one is in a closed plastic tray and another in an open tray. Two loggers have been placed on the floor in the northeast corner of the store in what was identified as a damp area in 2003.

As discussed in previous chapters the data presented in this chapter have been calibrated to take variations in the accuracy of individual loggers into account. All times quoted are in Greenwich Mean Time (GMT).

3.2.1 Annual Data Discussion

Figure 42 shows a general improvement in the conditions in both storerooms in the calendar year 2005 compared to the previous 12 months; Figure 43.

When comparing the two graphs we can observe similar seasonal variations for 2005 as 2004. The temperature readings in particular are very similar and, although the humidity curve has been changed due to improvements to the Petrology Store, the seasonal variations can still be seen.

The graphs show the expected seasonal trends of increasing temperature and humidity as the year progresses to mid- to late-August when it begins the slide into autumn and winter. The humidity generally follows this trend, although it is not as high as during 2004 in the last third of the year.

The weather was very cold for most of February and the first week of March, with a frost on the 8th. It became milder around the 17th March and this is reflected in the temperature and humidity curves rising.

As with the 2004 report I have divided the data into two groups: an 'Extreme Areas' group, consisting of the loggers that are in the problem corner and, for the first seven months of the year was in the foyer of the building before being moved to the Archive Room. These data for these areas are presented as Figures 44 and 45 and are discussed after those graphs. Data recorded for the last 6 months of 2005 in the Archive Room are presented in Figure 46.

All data are presented by range values and a 2004/2005 comparison in bar-chart format in Figures 47 to 54. From these charts is will be seen that the results for 2005 are encouraging although the humidity in one or two areas has dropped below the lower limit.

These charts are summarised in Figures 51 and 52, with the final charts, Figures 53 & 54 showing the percentage of data within the guidelines for 2005 & 2004 respectively.

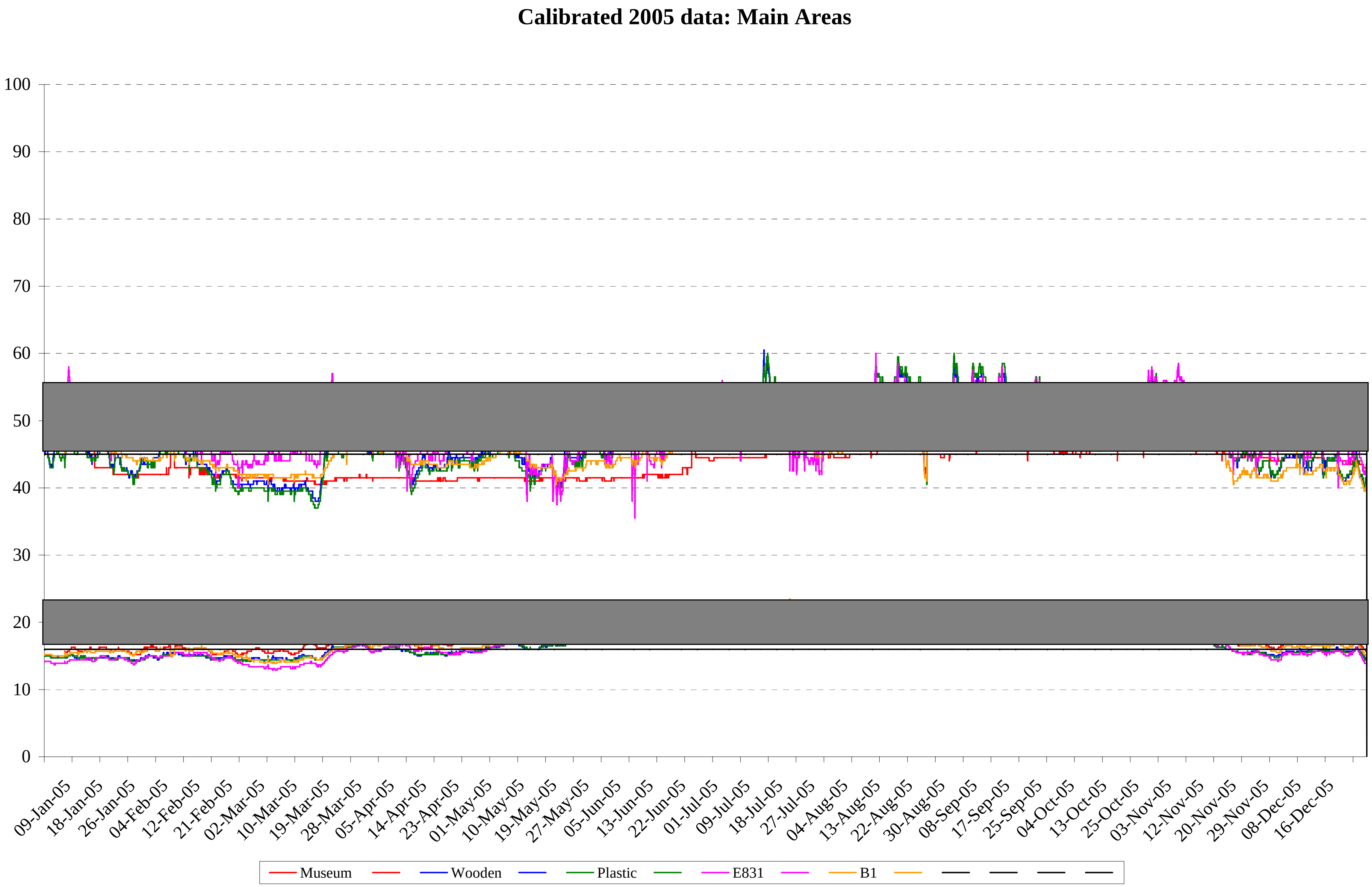

Figure 42: Calibrated data 2005: Main Areas, Murchison House

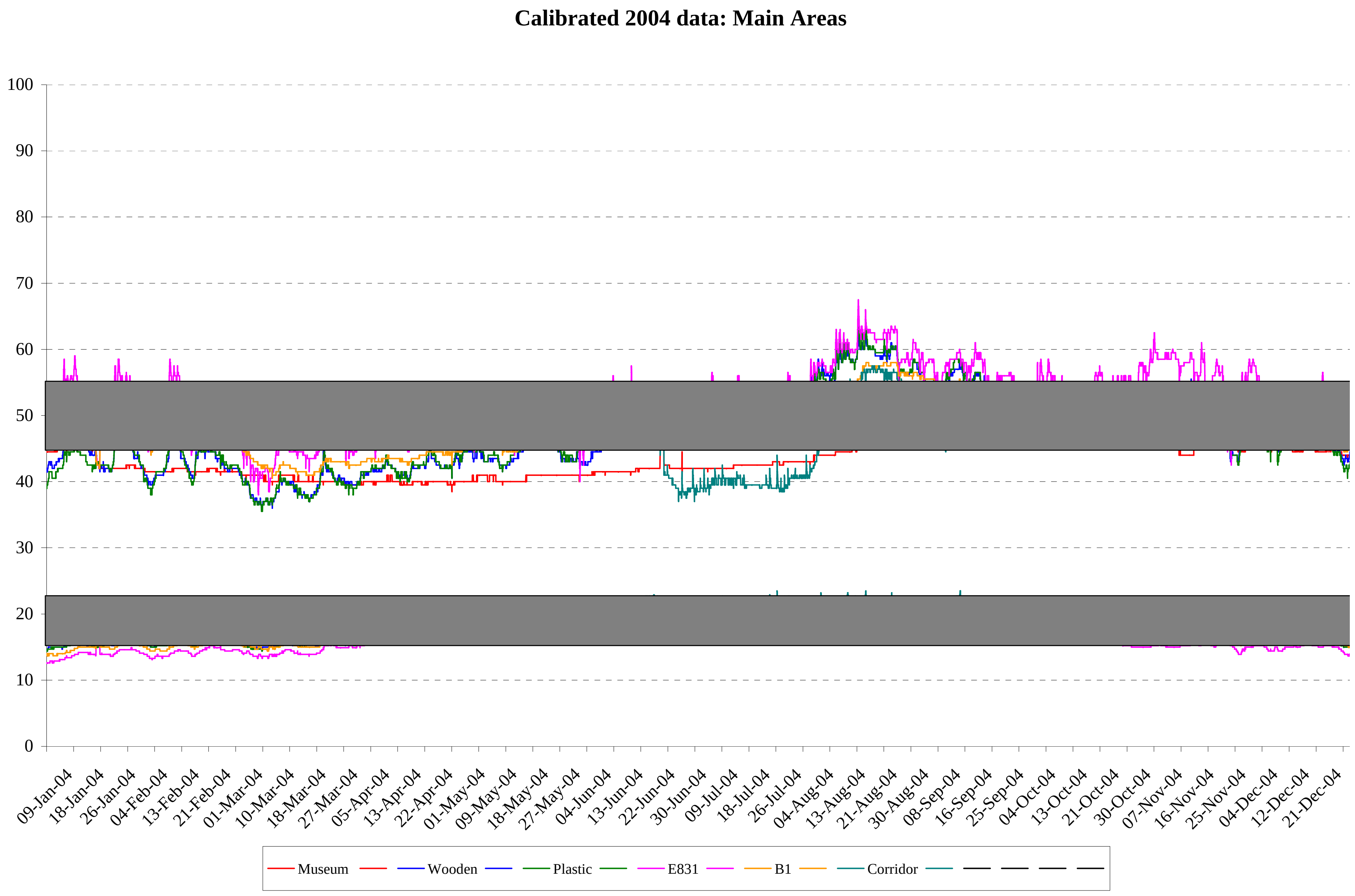

Figure 43 Calibrated data 2004: Main Areas, Murchison House

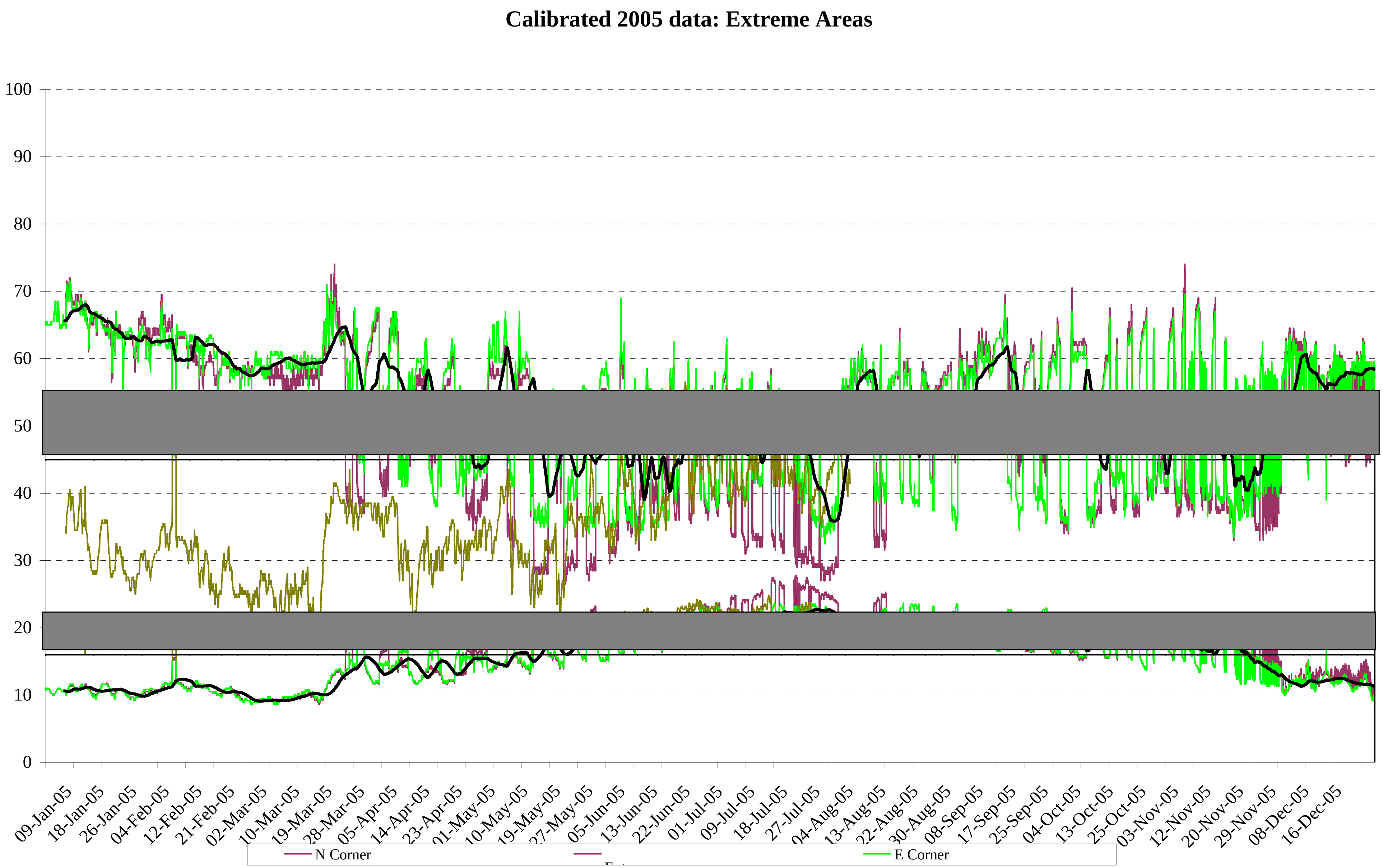

Figure 44 Calibrated data 2005:Extreme Area, Murchison House

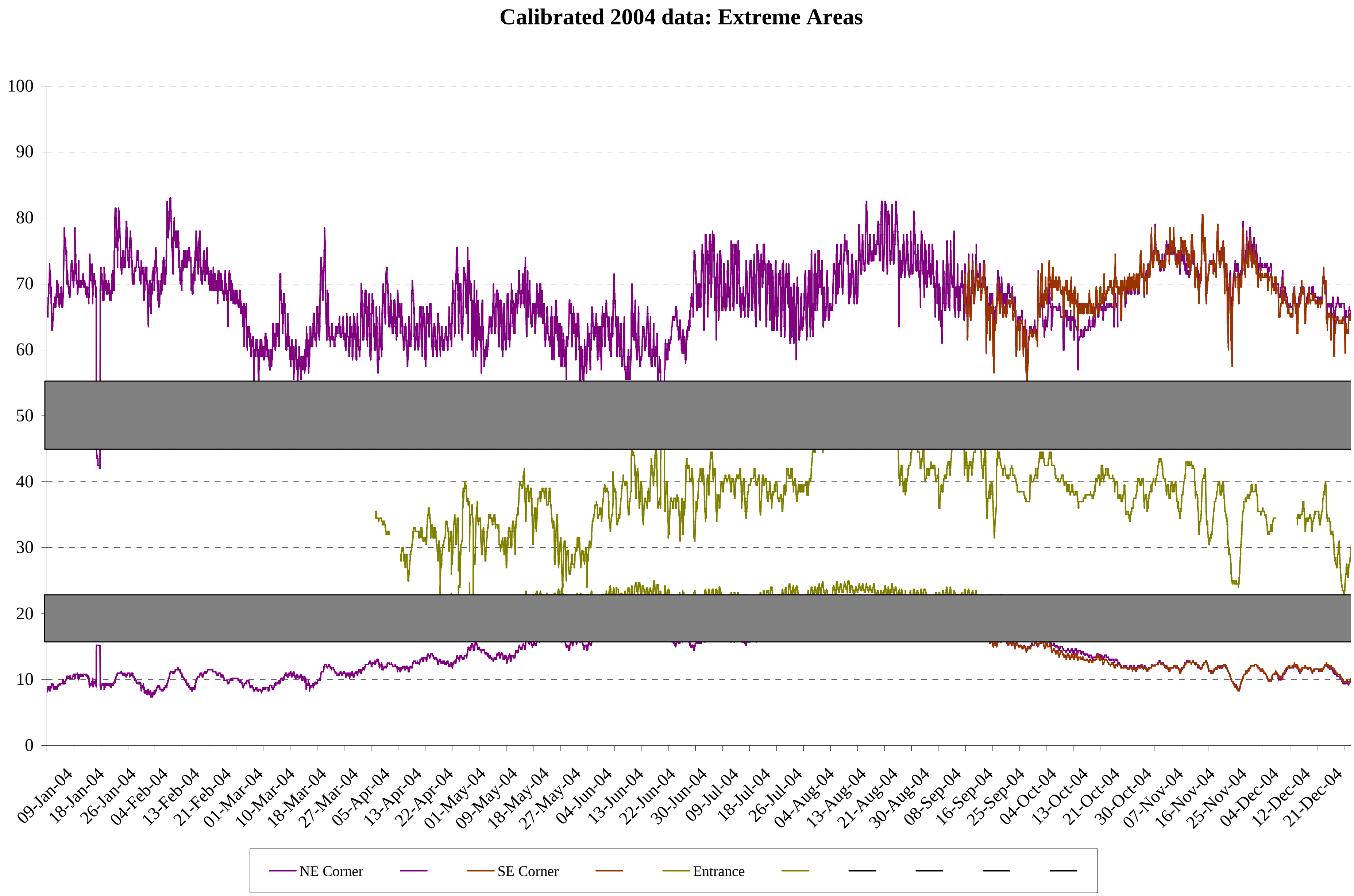

Figure 45 Calibrated data 2004:Extreme Area, Murchison House

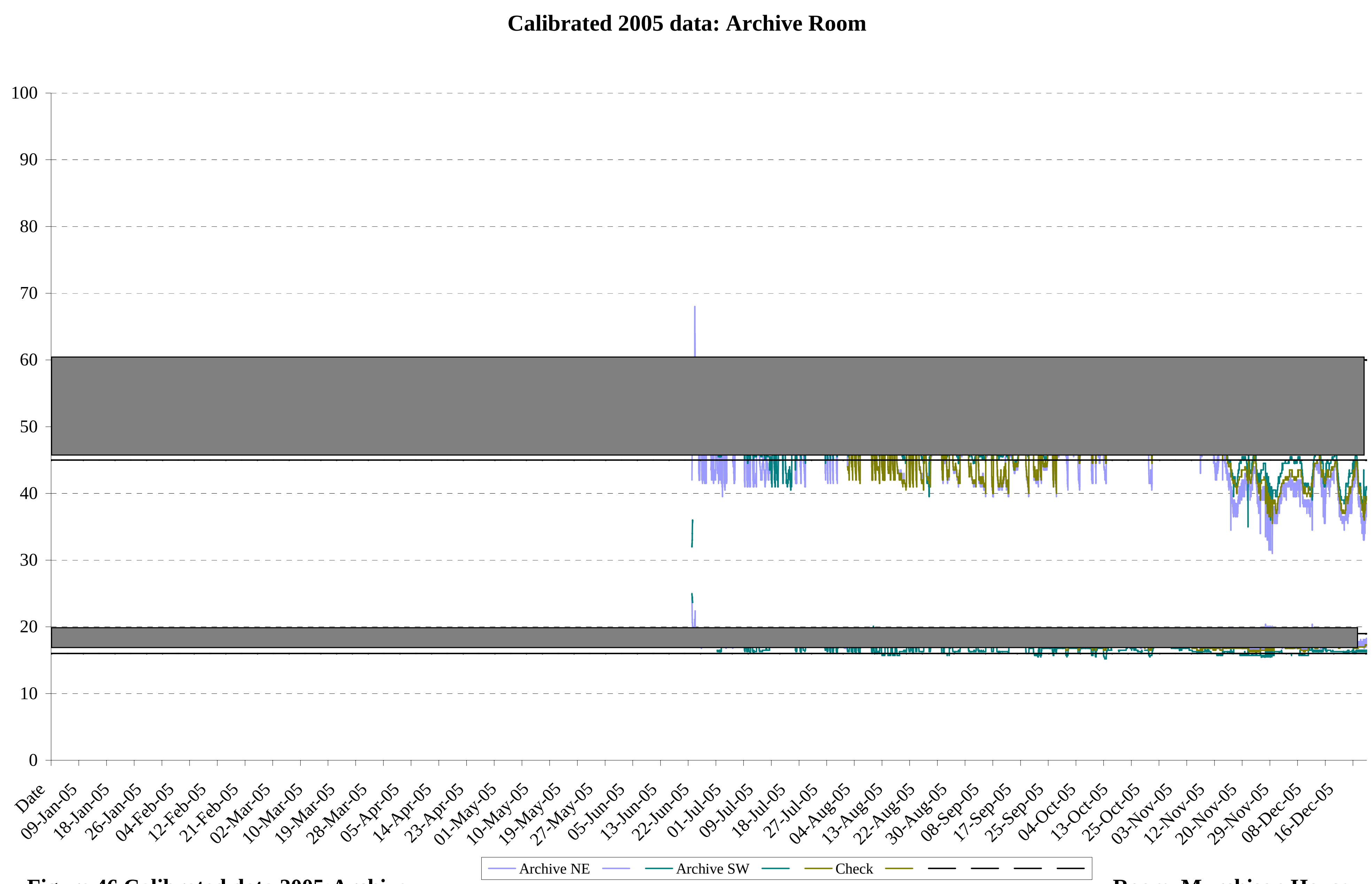

Figure 46 Calibrated data 2005:Archive Room, Murchison House

3.2.1.1 Extreme Area

A small, mobile dehumidifier was positioned in the "problem corner" beside the N and E corner loggers in March 2005. Initially it was set to maximum in an attempt to remove as much humidity from the area as possible. This was very successful and the container had to be emptied every two days.

The target bands for the temperature and humidity in Figures 44 & 45 have been greyed out to enable those readings that are out-of-limit to be viewed more easily. The NE & N Corners and the SE & E are equivalent. Comparing the two graphs it can be seen that the temperature during the first two months of both 2005 and 2004 were approximately similar whilst the humidity was higher in 2004.

It would be pleasing to say that this was entirely due to actions taken in 2004 but the lack of external data to compare would make this statement inaccurate as it could be down to external influences.

However what can be said with confidence is that the data after March 21 2005, when the dehumidifier was positioned, is very different to that in 2004. The humidity is 25% less over the summer period and the temperature higher than in 2004, even when the dehumidifier setting was reduced in August due to concerns that it was being too efficient in drawing out the moisture from the air and taking that below and the temperature above the upper limit. However this is a positive step and will be closely monitored.

As the loggers are separated by less than 1 meter it is not unexpected to see the record for one almost entirely overwritten by that for by the other.

What is unknown at this time is if the actions taken to improve this area have had an impact on the rest of the room and if so, to what extent.

One could surmise that, if damp, cooler air is being extracted from the atmosphere there will be a change in other parts of the store.

Examining the data for E831 and B1 in Figures 42 & 43 it can be seen that there is a positive reduction in the humidity for both loggers, particularly E831, which is the open tray closest to the corner.

3.2.1.2 Main Sample Areas

Referring to Figures 42 & 43: broadly speaking both the humidity and temperature are lower in 2005 than in 2004 in both stores.

The humidity of the logger sitting isolated from the others, the Museum, is higher than the lower limit for 6 months, compared to four in 2004. The temperature for this area is also lower but not of concern as it is generally within the range.

The other loggers are paired by the store in which they sit, the Palaeo store more so than the Petro. Once again this shows that the Plastic and Wooden trays react to temperature and humidity in the store in similar ways with little or no lag.

The loggers in the Petro store vary more but still move in line with the data collected from the loggers in the Palaeo store.

This shows that the changes are not man-made but influenced from outside. This is confirmed by examining the peeks in the humidity in Figure 42 which can also be seen in Figure 55: Weather 2005, Murchison House.

The test for us now is to ensure these external influences are lessened as much as possible. The addition of a small dehumidifier in the Petro store has reduced the humidity in that store considerably.

3.2.1.3 Archive Room

As the Archive Room is a new store there is no data to compare that collected during 2005 to, I shall therefore limit discussion in this chapter to a few comments.

The Archive Room was created in early 2005 and monitoring commenced during June 2005.

As the room has a computer monitoring the temperature & humidity and controlling both to within a pre-set range it was thought the environment would be constant and data logging purely a recording exercise. However we found that there were fluctuations in the data, see Figure 46.

The loggers installed in the Archive Room were borrowed from another project and had not been used by Collections before and so the accuracy unknown. A third logger from the Entrance was installed as a check and all three loggers were calibrated together in August 2005 in the usual manner, this provided data that we were confident was accurate, see Figure 41.

Fluctuations are seen in both the temperature and humidity, although only the humidity falls out of the range for the media type stored in this room. It is too regular to be atmospheric and so it is assumed that it is mechanical.

The equipment will continue to be monitored and alterations made to the settings when possible.

3.2.1.4 Discussion of Bar Chart Data

Data from the graphs are collected together in groupings above, below & within range and displayed in simple bar charts in Figures 47 & 49 with the comparable charts for 2004 provided as Figures 48 & 50.

Figures 51 & 52, provide a summary of Figures 42 to 46, Figure 53 providing the simplest breakdown of the 2005 data, showing the percentages of the data recorded lying within the target intervals.

From these charts it can be seen that the percentage of temperature readings within the required range in the Palaeo Store has dropped slightly whilst the humidity readings within range have increased.

The charts also show the improvement in the RH data within the Petro Store in all, other than one, B1, of the areas. However all the loggers in the Petro Store recorded an increase in the number of temperature readings. This is assumed to be due, in part, to the use of a dehumidifier. The removal of moisture from the air allows more of the heat to increase the air rather than water.

These results highlight the difficulty of attempting to control the environment without fully controllable equipment.

Unfortunately, due to the lack of external data for 2004, we cannot say if the average temperature for 2005 was higher or lower and therefore cannot provide a reason for the dip in effectiveness in maintaining the stores within the suggested temperature range. However I am pleased that the humidity has improved, although surprised that a logger in the Petro Store showed a drop in readings within the humidity range and can offer no explanation for this.

As this is the first year of monitoring the Archive Room there is no data to compare 2005 with and so comments are limited to noting the percentage of readings outwith the recommended range. This will be investigated and monitored during 2006.

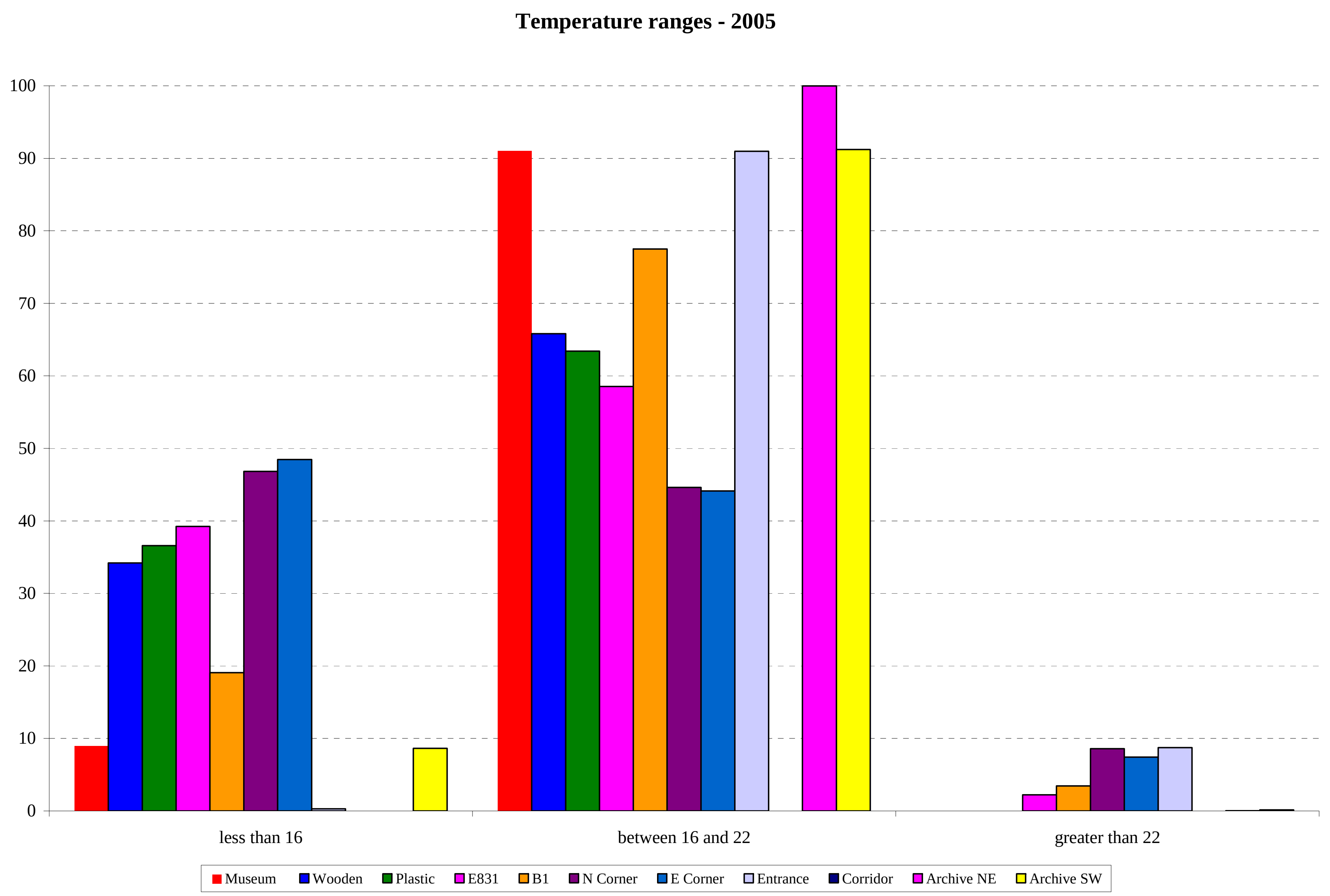

Figure 47 Temperature Ranges 2005

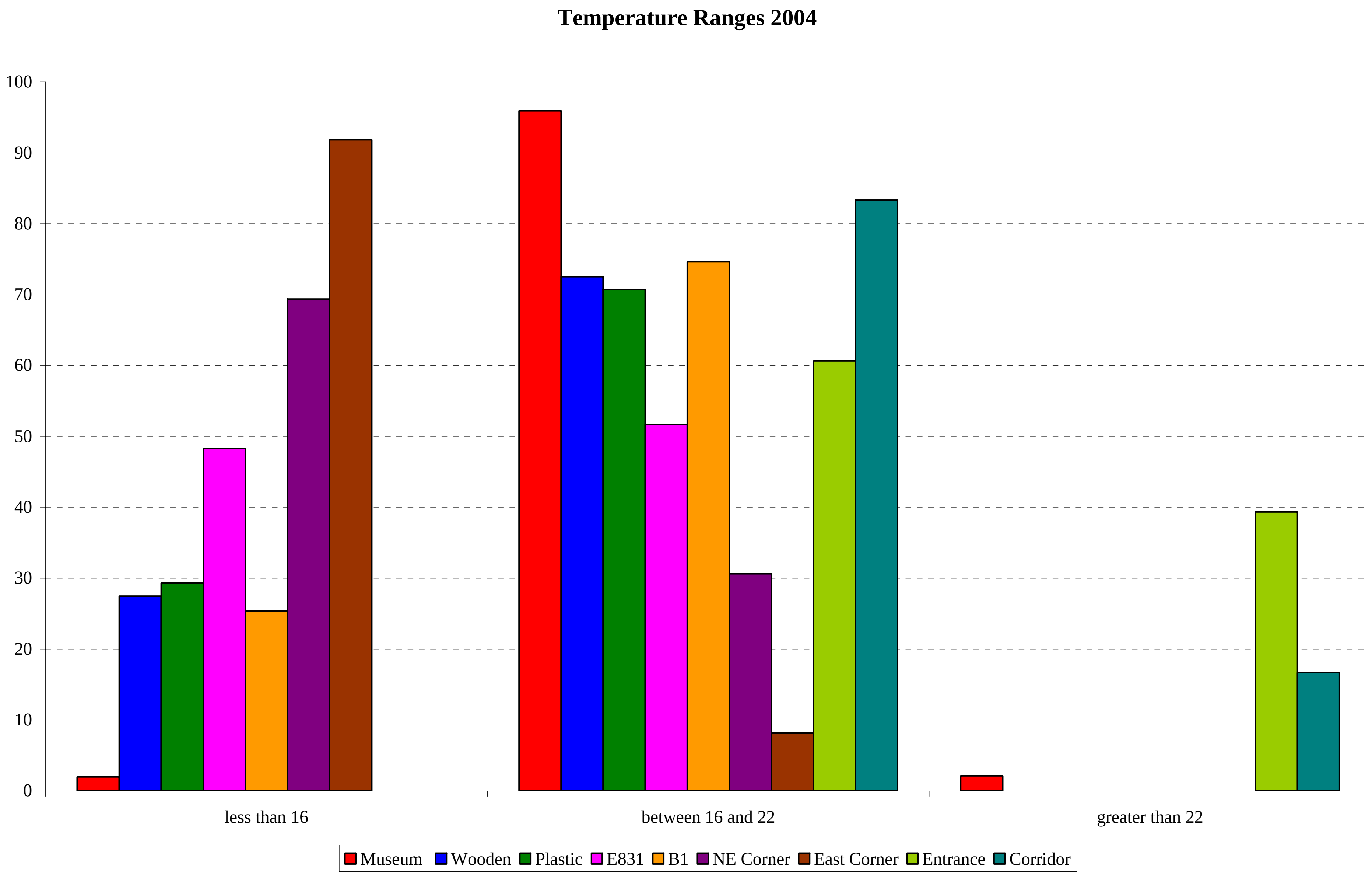

Figure 48 Temperature Ranges 2004

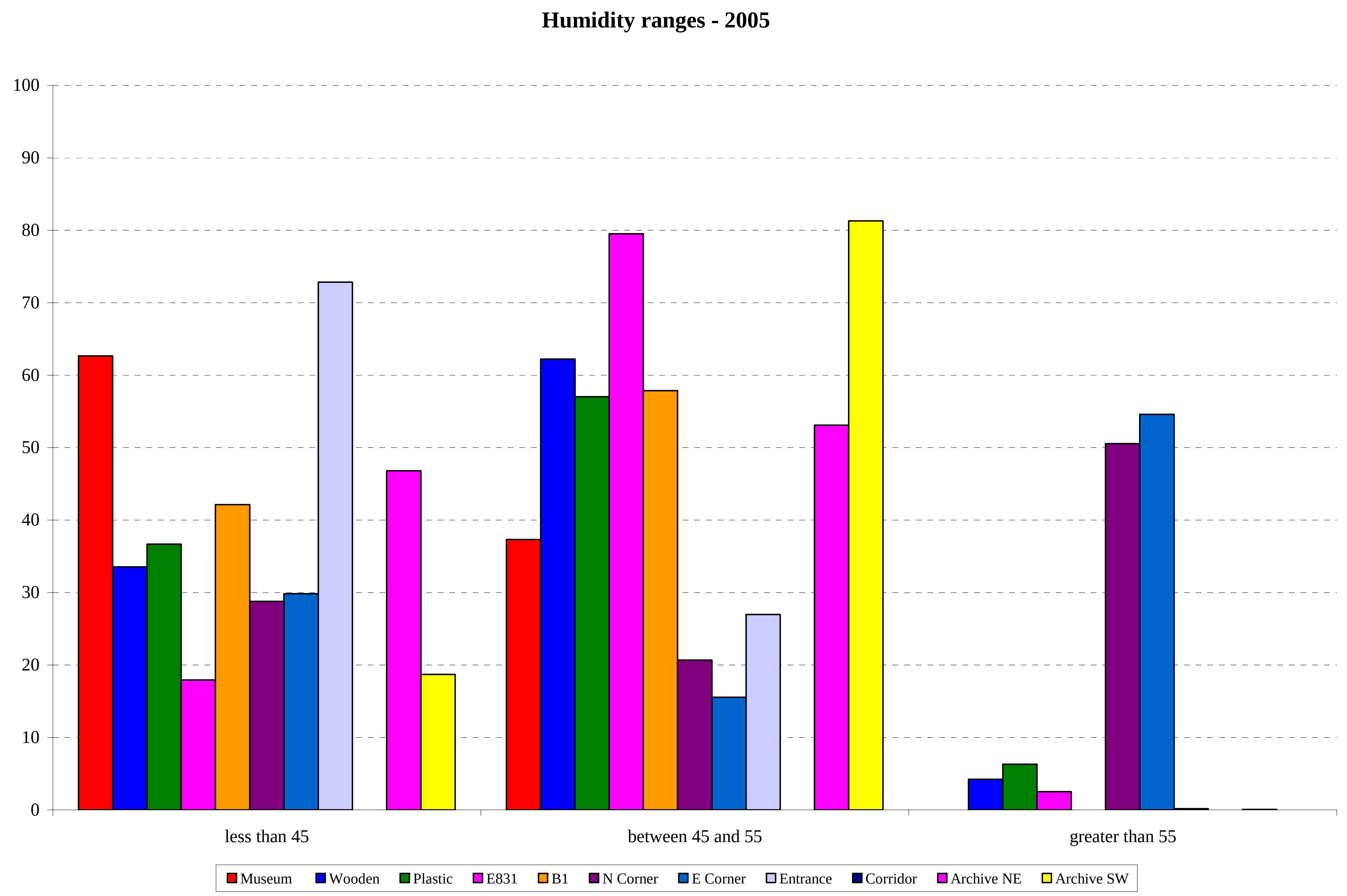

Figure 49 Humidity Ranges 2005

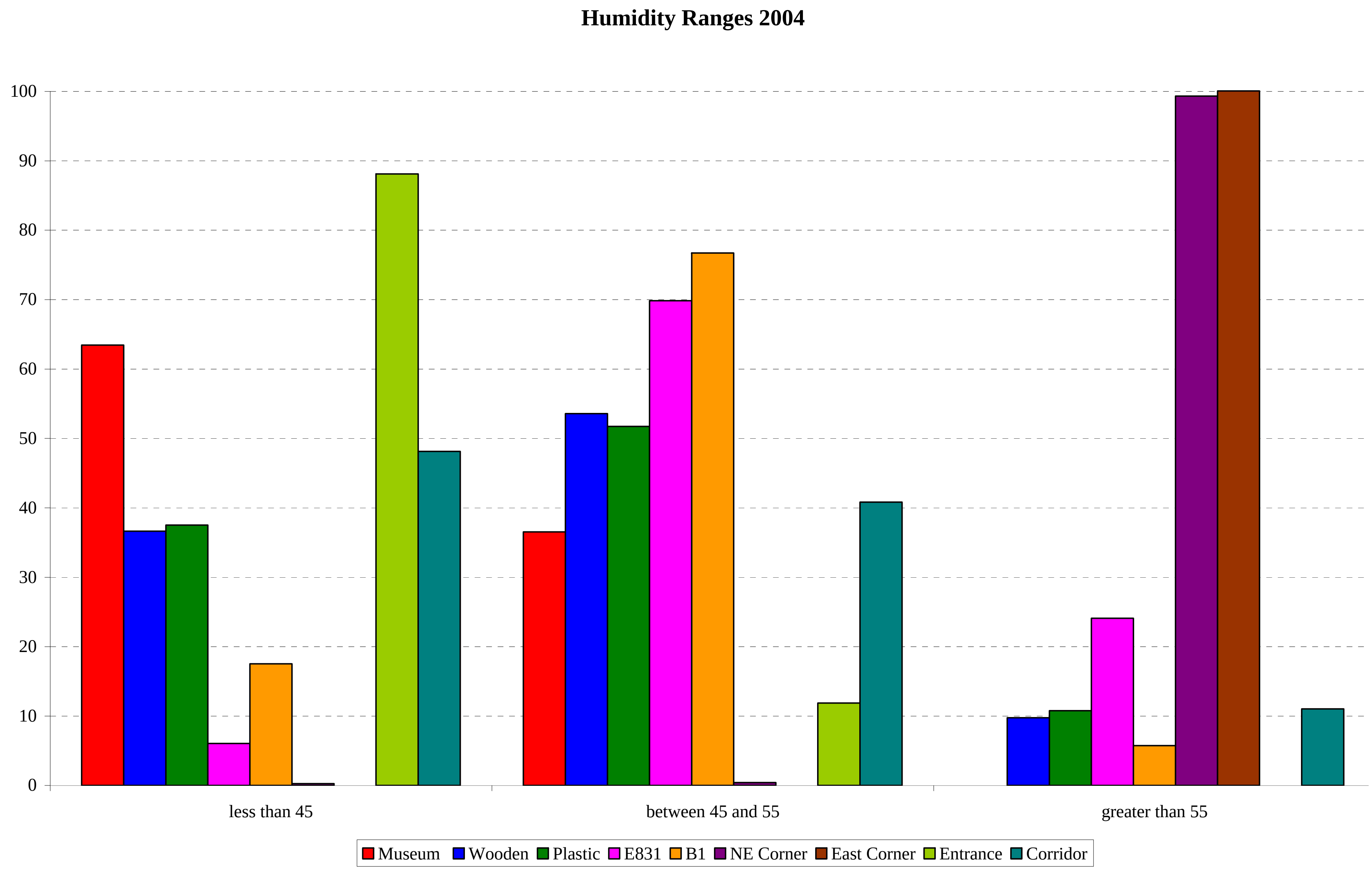

Figure 50 Humidity Ranges 2004

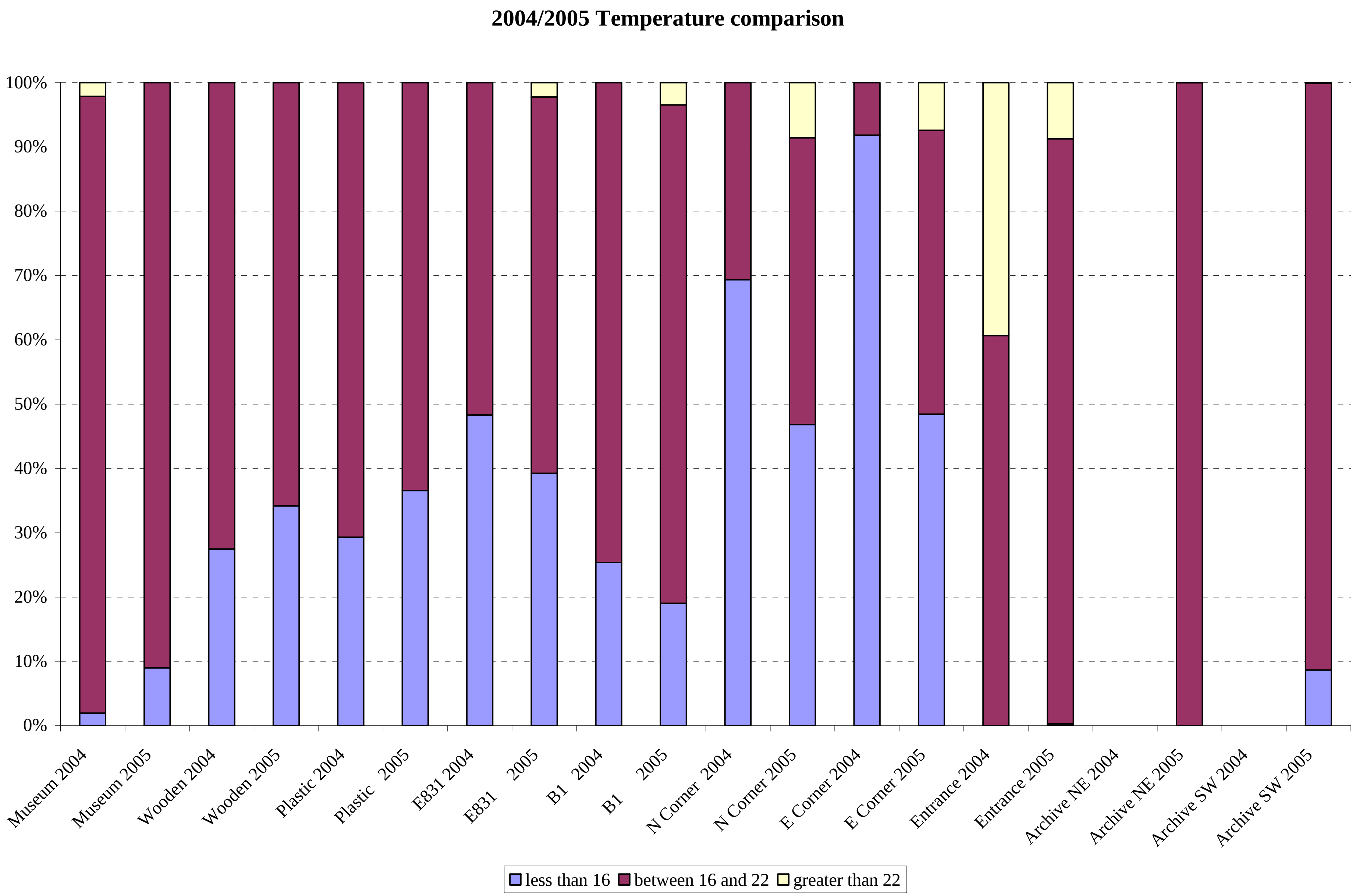

Figure 51: 2004/2005 Temperature comparisons, Murchison House

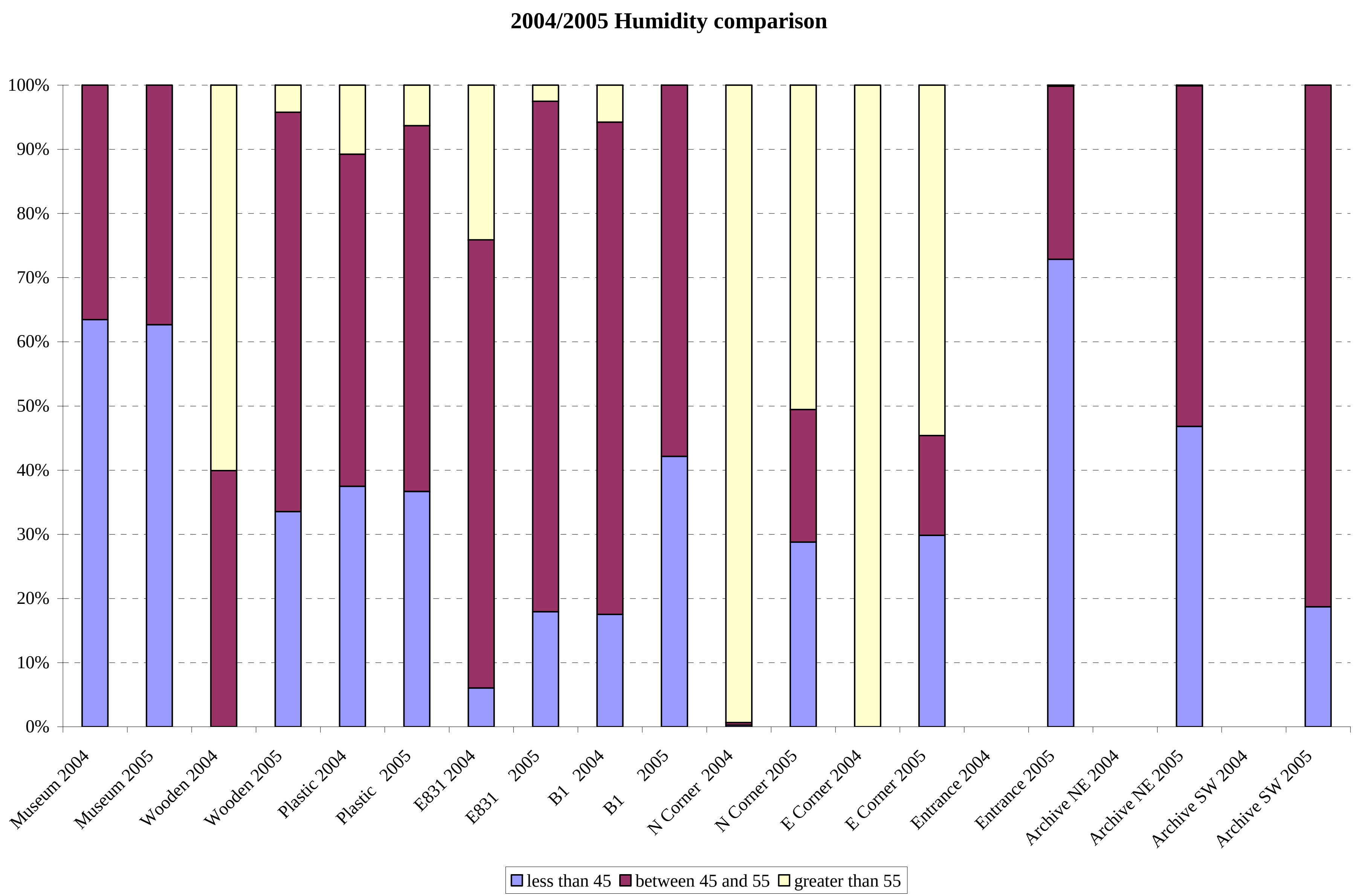

Figure 52: 2004/2005 Humidity comparisons, Murchison House

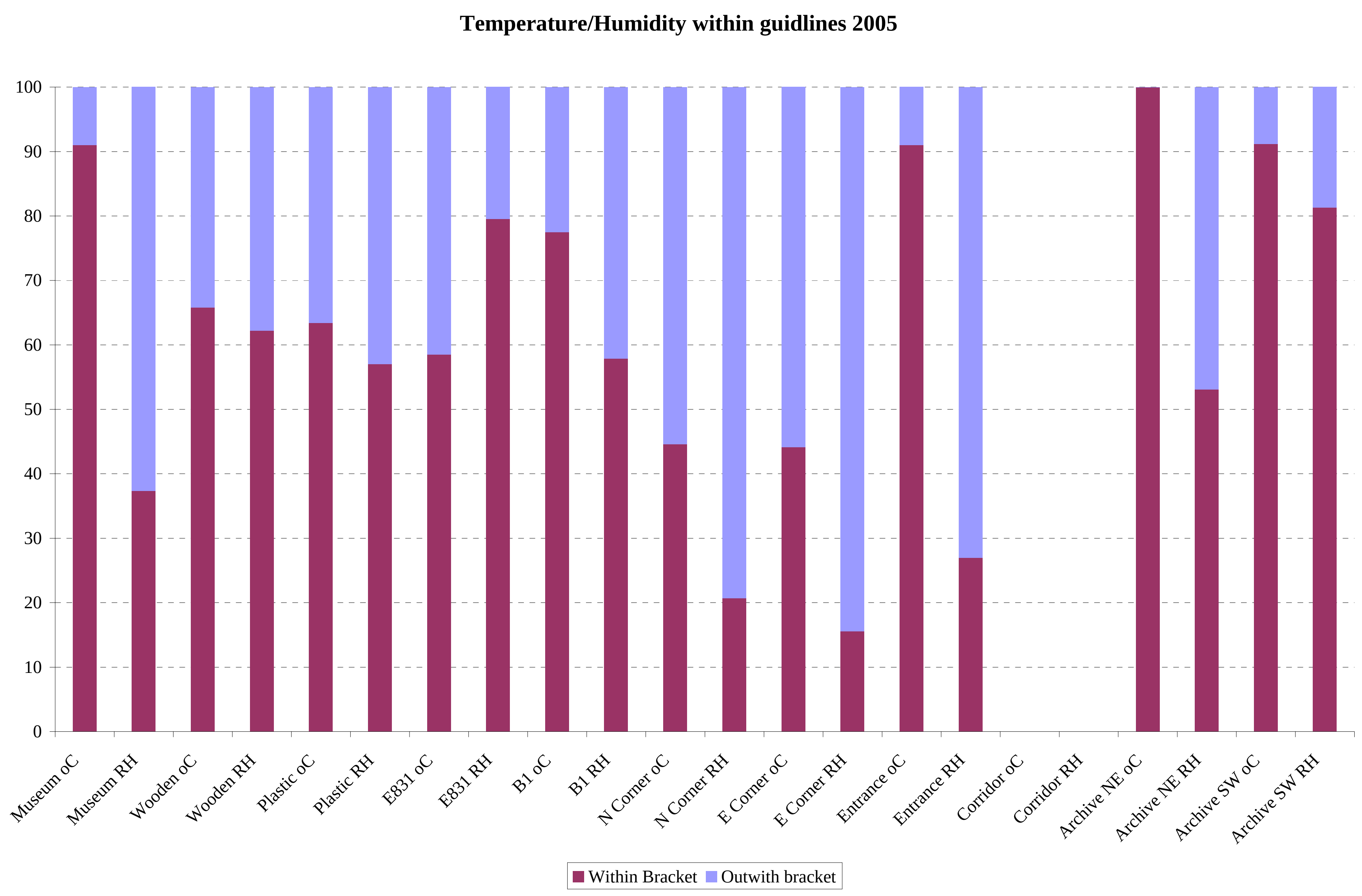

Figure 53: 2005 Temperature/Humidity target success breakdown, Murchison House

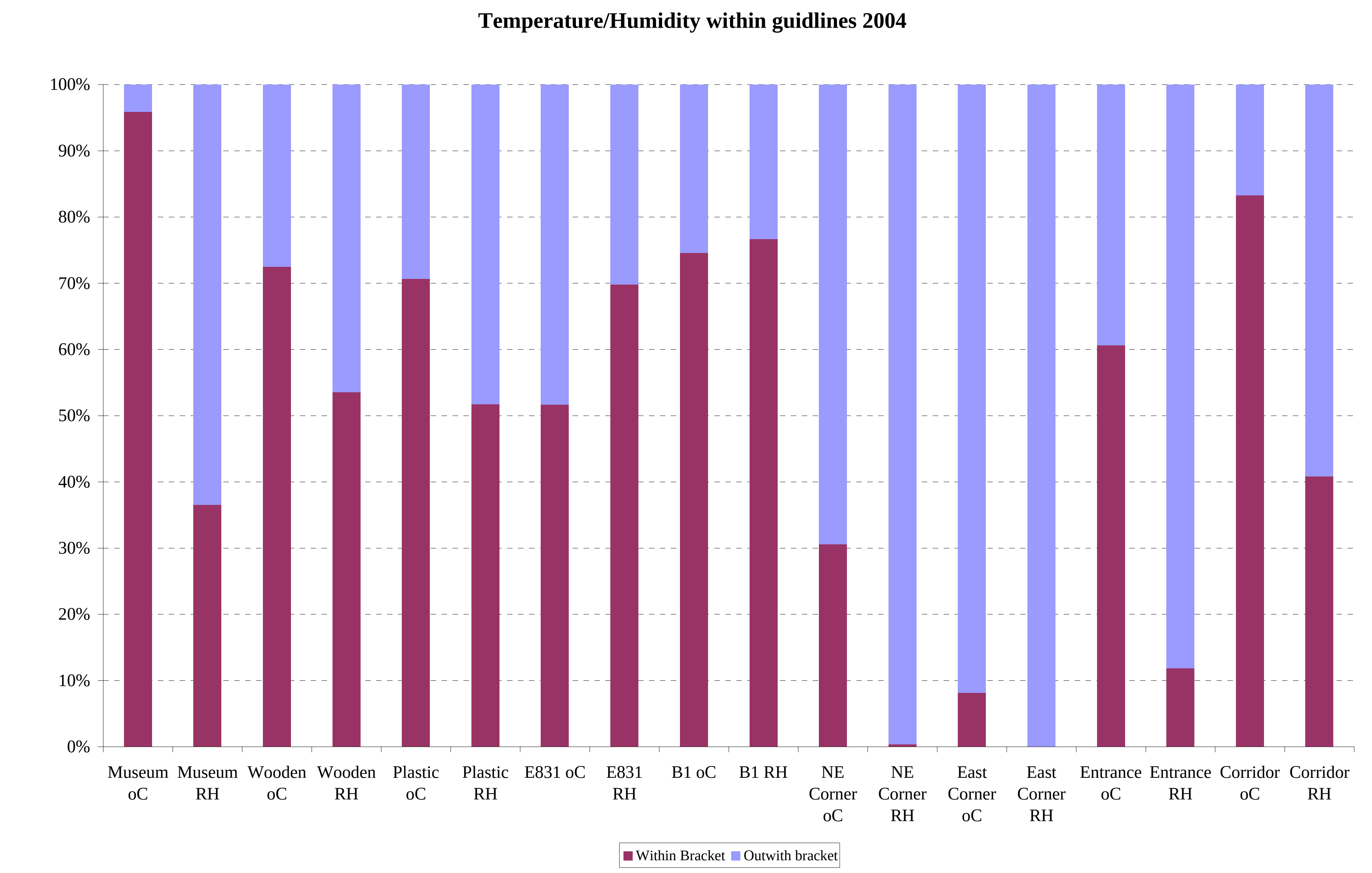

Figure 54: 2004 Temperature/Humidity target success breakdown, Murchison House

3.3 ANNUAL WEATHER DATA 2005

Analytical external data at Murchison House are recorded from a BGS built weather station situated on the roof of Murchison House. Data are recorded on a desktop computer and automatically stored in files in one-second intervals but extracted in 24-hour files.

The computer used to record the data from the weather station remains unstable, the cause of which is not yet known.

The weather station was moved during 2005 to the northwest of the Murchison House roof, a location more suitable for referencing against data recorded in the Collections stores. The management of the weather station was taken over by Tulloch: this has proved successful in recording a more complete set of data for the calendar year achieved, in part, by utilising a desktop viewer to monitor the data in real time, which allows computer crashes to be identified more promptly.

The recording of this data will provide in future years data against which we can plot changes in the environment of the various stores to enhance comparative discussion.

The weather station has not been calibrated against the other loggers in the suite and therefore its accuracy is unknown and the data cannot be directly compared with that from the other sources, however the trend can be observed and compared.

It is my intention during 2006 to place a logger beside the weather station to allow a crude calibration to be carried out.

Data from the weather station will become more useful in time. The trends and changes it records will allow us to better understand the changes in the internal environment and thereby allow us to resolve some of our problems.

3.3.1 Annual Weather Discussion

For clearer examination of the weather data two trend lines have been included in the graphs. One at a 50-point moving average to remove the maximum & minimum reading that clutter the graph, the other at 1000-point moving average allows the annual trend to be identified.

By including the rainfall figure (multiplied by a factor of ten for clarity) we have most of the external factors that influence the environment in the various stores on one graph.

From the data plotted on Figure 55 we can see, unsurprisingly, that the humidity increases after a period of rain. How large an increase is dependant on the duration of the rain and the ambient temperature.

Given the problems discovered with the fabric of the building reported on in previous years it is unknown at this time if it is the increase in external air humidity that, once it enters the building, affects the internal humidity, or if it is rain water ingress through the brickwork.

The use of the newly acquired damp meter will hopefully allow us to determine this and suggest working method to resolve this issue.

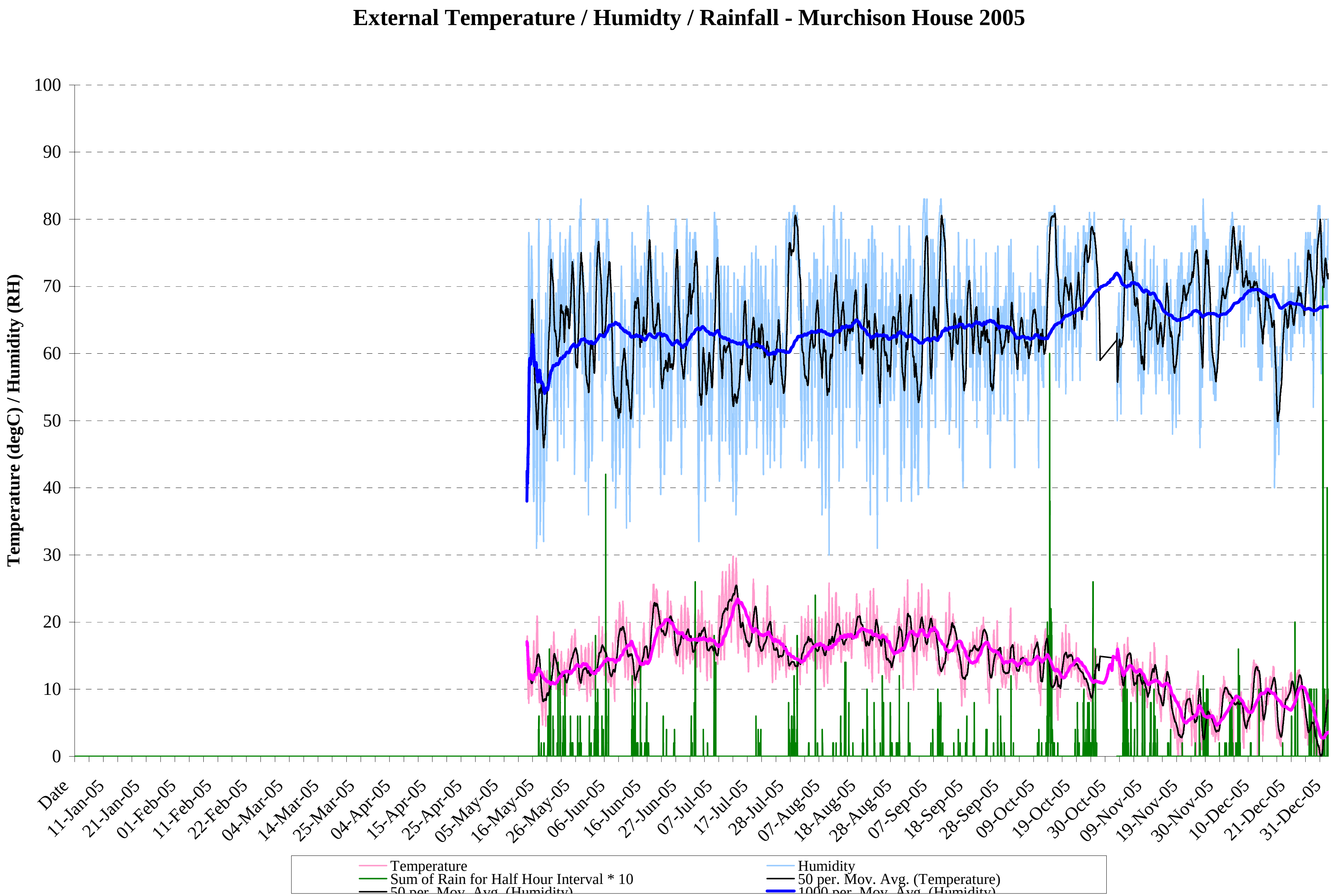

Figure 55: Weather 2005, Murchison House

3.4 MINI PROJECTS

The 2005 project was to take over the management of the weather station to improve the data recording. This was eventually completed in May 2005 and data has, more or less, been constant since that time.

In addition to the temperature & humidity recorded previously a rainfall gauge was installed and data from the anemometer is now being recorded. This data will be displayed in coming reports.

The Archive Room was added to the areas under environmental recording and the addition of three Digitron loggers in that space has increased the amount of data gathered.

Following a TNA Audit in Edinburgh in September it was suggested that both the Loanhead & Gilmerton core stores should be monitored. A proposal to purchase four loggers for each site was submitted and these will be installed during 2006.

3.4.1 Results of 2004 Mini-Projects

3.4.1.1 Damp Meter

A damp meter has been purchased and will be used during 2006 to monitor the temperature and humidity of the brickwork of the stores, particularly those areas that show large fluctuations in humidity, N and E Corners for example, but also other areas of interest.

3.4.1.2 Monitor Differences in Open and Closed Aisles

This was not carried out during 2005 however a timetable will be drawn up and recordings made during 2006.

3.4.2 Future Mini Projects

3.4.2.1 Damp Meter

As stated above a meter has now been purchased and the results of monitoring will be published in the next report.

3.4.2.2 Monitor Differences in Open and Closed Aisles

A timetable will be drawn up to allow the monitoring of the mobile racking whilst the racks are open and closed. The movement of the racks will be monitored and the data examined to determine if there are benefits in keeping the racks open or closed.

3.4.2.3 Continued Monitoring of 'Problem Corner'

The comparative study of the NE Corner will be continued.

The results examined to ensure the de-humidifier is benefiting the environment. This may have effects on equipment purchase for Facilities Management.

3.4.2.4 Extend Monitoring to the Loanhead & Gilmerton Stores

The purchase of 8 loggers will allow the project to extend the monitoring of the environment within its storerooms to two remote stores at Loanhead and Gilmerton. These stores house core samples from mainly the offshore arena, although Loanhead is a multi-user facility as it also houses onshore material. It is also the repository for a number of magnetic tapes and overspill

Library and Drawing Office store. The building is also shared with the marine equipment pool, which means a certain amount of fabrication is carried out in the premises.

3.5 RECOMMENDATIONS FOR EDINBURGH

The recommendations laid down in the first report in this series will continue as they have proved to be robust. The loggers in place will remain and the present ‘mobile’ logger and any new instruments purchased will used as 'trouble-shooters'.

Areas identified, or suspected, as being problematic should have a logger placed in them to monitor the conditions for a limited time to determine the condition of the environment and, therefore, action to be taken to rectify any problems.

This rationale will also be used for rooms being used as temporary stores. 'Mobile' loggers will be placed in them prior to data or samples. The measurements will be downloaded and interrogated as the area is being occupied and the loggers replaced and monitored for changes over the time of occupancy.

The damp meter will be used to monitor the levels of moisture in wooden boxes and brickwork; this may, after a period of time having collated a number of years worth of data, assist in the discovery of pyrite decay or efflorescence, or identify trays where the environment would allow such decay to occur in the future.

The dehumidifier settings will be changed routinely and the effect on the recorded environment noted. This will allow a strategy for this piece of equipment to be built.

Collections continue to work closely with Facilities Management in identifying and resolving problems where possible. This proved successful in the past and is vital that it continues. Unfortunately, what is becoming evident is that all the low-cost adjustments to working practices have been taken and to improve the environments within the stores further expenditure on equipment is now required.

4 Conclusion

4.1 CONCLUSION FOR KEYWORTH

Monitoring of all existing areas within the Corporate Collections, NGRC and Library has continued during 2005. The monitoring of weather station and a Museum drawer has also been implemented.

During 2005, the Core Store and Museum are within the acceptable temperature parameters for at least 67% of the time. However humidity values for these areas are not as encouraging as they are only within acceptable parameters for a minimum of 24% of the time. Therefore we need to look at ways in which to raise the humidity within these areas concerned.

The Cold Store is running effectively at maintaining readings within the recommended parameters for the storage of fresh borehole material in barrier film for 99% of the time.

For the conservation laboratory and main corridor, the temperature readings are within parameters for on average 40% of the time, where as the humidity is only for 20% of the time. Humidity readings over a trail period, to try an increase the humidity have shown improvements. These readings are promising and further tests should take place especially during periods of lower humidity.

For the storage of sub-fossil bone, which recommends more specific parameters than the general material. Larger sub-fossil bone specimens on top of the cabinets are within the temperature and humidity ranges for only 63% and 10% of the time respectively. The majority of this type of material is within wall cabinets, which should provide better buffering properties, nevertheless measures should still be taken to try and improve the conditions for these larger specimens until a suitable storage area can be found.

During 2005, it can be seen that the NGRC and strong room are showing similar trends as 2004, with weather variations affecting internal readings on a seasonal basis. The cardboard boxes seem to show no major buffering effects from the surrounding environment, whereas the strong room shows slightly higher temperatures than the records room, and considerably higher humidity, these however are closer to the recommended humidity ranges. Under the British Standard BS 5454:2000, as a 'Place of Deposit', temperature readings are above the recommended maximum for most of the time, whilst the humidity values are within the recommended guidelines for 26% and 74% of the time for the records room and strong room respectively. We can see from this that the temperature needs reducing in both these areas, whilst humidity levels needs to be dramatically improved within the Records rooms. The Strong room is providing a more reasonable environment however there is always room for improvement.

Under the British Standard BS 5454:2000, the Library strong room shows temperature readings are 47% of the time within range, whilst humidity values fall within these guidelines for only 39% of the time. Since the installation of the air conditioning system, we have seen a decrease in temperature, whilst humidity levels have increased. Irregular variations in humidity using the new air conditioning system have been bought to the attention of Facilities Management, and the possible causes are being investigated. This situation needs to be continually monitored to assess the effectiveness of this new system, in order for us to see the benefits in the long term.

Currently both the Library and the NGRC do not fully comply with the British Standard BS 5454:2000 throughout the year.

It is fundamentally important to strive to achieve and implement the changes needed for the ideal recommended parameters for the storage of the materials within the Collections.

4.2 CONCLUSION FOR EDINBURGH

As reported previously, the Collections are housed in rooms ill suited and under equipped for the task. The programme of monitoring the temperature and humidity is vital to the safe keeping of the specimens and has already highlighted and resolved a number of issues.

Neither the Palaeontological or Petrological storerooms have an ideal environment for storing sensitive geological specimens. The rooms have no heating and, as a consequence, there are fluctuations in both the temperature and humidity of both rooms; neither meets the suggested parameters for specimen storage.

Repairs to the fabric of the building have been made and working practices updated which has led to an improvement in the conditions in the rooms concerned. These changes have been monitored and recorded and provide the basis for the continuing care of the Collections. The programme of environmental monitoring is important to the preservation of the Collections and should be continued.

The installation of a small, portable dehumidifier in one area of the Petrology Store has improved the environment of that store. The use of this equipment will be monitored and trends examined with a view to possibly introducing others as required in other stores or areas within the same store.

Purchase of loggers for Loanhead & Gilmerton will allow the environment of these stores to be recorded, however the buildings are too large to allow an effective strategy to improve the space and so this will simply be a monitoring programme.

Appendix 1 Summary of the Strategy for Environmental Control

STRATEGY

1. Determine from appropriate sources (publications, meetings, personal communications, internal research, etc.) current best practice guidelines for the storage of the various materials types found within the NGMC. The guidelines should include the range and permissible variation of ambient temperature and of ambient relative humidity.

2. Routinely monitor temperature & Relative humidity in all storage areas, including conditions within typical trays, drawers, boxes and cabinets. Monitor external weather conditions where possible.

3. Review effects of room temperature and humidity on container temperature and humidity. Where the latter vary outside target limits, consider whether improvements can be made in the room parameters. Where temperature and/or Relative humidity readings indicate building/heating/ventilation defects, advise appropriate authorities.

4. Where trays or drawers vary outside these limits, microclimates must be used.

5. Implementation priority must be given to Museum Collection fossils and new borehole material.

PROCEDURES

Acceptable Temperature & Relative Humidity limits

1. Acceptable storage conditions for geological specimens (Doughty & Brunton, 1993)

Pyrite & Maracasite	16-22°C	<55%
Sub fossil bone, tusks, teeth	16-22°C	>40%
Fossils with shale/clay matrix	16-22°C	>40%

Storage Guidelines

2. All items should be stored in closed containers whenever possible.

3. Where pyritised fossils are to be stored in containers where humidity's may rise over 55%RH, they should be kept in microclimates, buffered with artsorb to 40%RH.

4. All pyritised fossils that have suffered pyrite decay should be stored in microclimates, buffered with artsorb to 40%RH.

5. Fresh borehole material, where organic or sulphide content is important, should be stored in barrier film, with Oxygen scavengers, in the cold store at 4°C.

Monitoring Guidelines

6. Monitor temperature and relative humidity readings on a regular basis, i.e. every 3 minutes, starting on the hour.

7. Monitors should be downloaded into a suitable digital format on a weekly basis.

8. Where possible, monitors should be calibrated on a regular basis, i.e. once a year, or when new loggers are purchased, so they can be used as a benchmark.

Appendix 2 Keyworth Data

Adobe® Acrobat® version of this report.

<u>2 Main Folders : 2004 & 2005</u>

<u>2004 has six main sub-folders: -</u>

<u>30 Minute Extracted Data</u>
- 19 sub folders for each locality monitored during 2004. All data calibrated converted to GMT where necessary and extracted to every 30 minutes.

<u>Calibration Data</u>
- Calibration period data in both lcf and csv format and Thermohygrograph data
- Grouped data for both prior and after the calibration period.

<u>Raw Data in csv format</u>
- 18 Sub folders, for 2004
- Raw data in csv format, for each monitor number including Thermohygrpgraphs and the weather readings.

<u>Raw Data in lcf format</u>
- 15 Sub folders for 2004
- Raw data in lcf. Format, for each monitor number including Thermohygrpgraphs and the weather readings.

<u>Yearly Histogram data 2004</u>
- Yearly histogram data for the main areas during

<u>Data under new parameters</u>
- 6 sub folders including most main areas in 30 minute extracted and calibration format

<u>2005 has six main sub-folders</u>

<u>30 Minute Extracted Data</u>
- 14 sub folders for each locality monitored during 2005. All data calibrated and extracted to every 30 minutes.

<u>Calibration Data</u>
- Calibration period data in csv format and Thermohygrograph data
- Grouped data for both prior and after the calibration period.

<u>Raw Data in csv format</u>
- 14 Sub folders, for 2005
- Raw data in csv format, for each monitor number.

<u>Raw Data in lcf format</u>
- 15 Sub folders for 2004
- Raw data in lcf. Format, for each monitor number including Thermohygrpgraphs and the weather readings.

<u>Report Images</u>
- Report images used for 2005 report

<u>Yearly Histogram data 2005</u>
- Yearly histogram data for the main areas during

Appendix 3 Edinburgh Data

Adobe® Acrobat® version of this report.

Four folders: -

2004

- 2004 Data.xls (Calibrated/GMT adjusted data for the year in MSExcel format).
- Bar graphs 03-04.xls
- Calibration 2004.xls
- October 2004.xls
- Converted files Folder
    - 12 folders containing raw data in monthly folders in Comma Separated Value (csv) format (readable by MSExcel).
- Logger files Folder
    - 12 folders containing raw data in monthly folders in original format as downloaded from loggers (lcf format).

2005

- MH 30 Minutes 2005.xls (Calibrated/GMT adjusted data for the year in MSExcel format).
- Internal & External.xls
- Calibration 2005.xls
- Bar graphs 04-05.xls
- 2004&05 comparison.xls
- Converted files Folder
    - 12 folders containing Raw data in Comma Separated Value (csv) format (readable by MSExcel) in monthly folders.
- Logger files Folder
    - 12 folders containing Raw data in original format as downloaded from loggers (lcf format) in monthly folders.

Access Files

- All environment data.mdb - Store room data
- MH Met data - 2005.mdb - Weather station data

Met Data

- 30 minute Met data.xls

(Due to pressure of space on this CD no original Met data has been provided)

Glossary

BGS - British Geological Survey

BST - British Summer Time

CSV - Comma Separated Value (file) .csv

GMT - Greenwich Mean Time

LCF - Logger Compact File .lcf

NGRC - National Geological Records Centre

RH - Relative Humidity

MTA - Murchison House Weather Station, Temperature readings, .MTA

MHU - Murchison House Weather Station, Humidity readings, .MHU

SNS - System Network Support

TNA - The National Archives

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Most of the references listed below are held in the Library of the British Geological Survey at Keyworth, Nottingham. Copies of the references may be purchased from the Library subject to the current copyright legislation.

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