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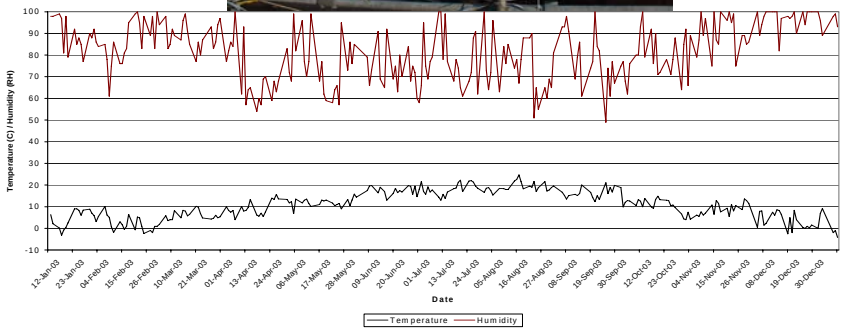
The Monitoring of Environmental Conditions within Corporate Collections at Keyworth and Murchison House: 2004

Information Management Programme

Internal Report IR/05/039



BRITISH GEOLOGICAL SURVEY

INTERNAL REPORT IR/05/039

The Monitoring of Environmental Conditions within Corporate Collections at Keyworth and Murchison House: 2004

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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)

Bibliographical reference

SHEPHERD, P, TULLOCH, G.J. 2005. The Monitoring of Environmental Conditions within Corporate Collections at Keyworth and Murchison House: 2004. *British Geological Survey Internal Report*, IR/05/039. 1691pp.

Keyworth, Nottingham British Geological Survey 2005

BRITISH GEOLOGICAL SURVEY

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The British Geological Survey is a component body of the Natural Environment Research Council.

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Foreword

This report second 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:

Susan Martin for downloading the environmental data when I have been unable to do so.

Susan Martin & Louise Neep for assisting with the recording of meteorological readings at the Keyworth Weather Station.

Susan Wheeler for photographing the 2004 hygrograph plots.

Contributions from Joan Bird, Chris Wheatley & June Wright

Graham would like to thank Luis Albornoz-Parra and Eileen Callaghan who downloaded the Edinburgh loggers and highlighted events he thought required attention.

Photograph credits:

Plates 1, 3 - 10	Susan Martin
Plate 2	Paul Shepherd
Cover photograph	Graham Tulloch

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Summary

This report presents the environment data gathered during the calendar year 2004 in the storerooms for the British Geological Survey's Corporate Collections Archives.

The report follows the pattern laid down in the first in 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.

The data are discussed in chapters 2 and 3 where they are also illustrated in graphical format. A full copy of the data is contained on the accompanying compact disk, together with an Adobe Acrobat format version of this report.

We will discuss the factors that affect the temperature and humidity of the storerooms, including the duration and number of workers present in the room, heating cycles of the building and external influences such as variations in the weather, from temperature and precipitation to the direction of the wind.

Alterations to working practices and improvements in the fabric of the stores over the period of reporting will also be discussed. Possible future modifications are identified, however these are made in a controlled manner to allow changes in the environment to be assessed.

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. 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%
Sub-fossil bone, tusks, teeth: fossils with scale or clay matrix	16-22°C	Not Below 40%
Historical Records		
Documents on Paper	13-18°C	55-65%
Modern Records		
Magnetic recording media	18-22°C	35-45%

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

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 the most important single collection 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 held within the Palaeontology and Mineral and Petrography stores in Murchison House.

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.

Data from an external logger is also available and, although on a different elevation of the building to the storerooms, provides a useful comparative dataset to those 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.

It must be noted that the Casella 500+ readings have not been used in this report. This is mainly due to the inaccurate readings recorded by the temperature and humidity probe. Additionally due to its size, the monitor could not be included throughout the calibration period. The readings obtained would have portrayed an inaccurate account of the conditions within the first floor of the museum.

Other instruments used include two Thermohygrographs.

2 Monitoring at Keyworth

At Keyworth, readings from fourteen monitors have been used to produce this report. In addition to the permanent monitors used during 2002 and 2003, the existing mobile monitor has been placed in the main corridor of the Core Store as from August 2004. Three new monitors have been set-up to record data within various locations of the NGRC. In the museum an additional two monitors, have been housed on separate floors. The monitor on the first floor was a direct replacement for the Casella 500+. New localities within this report include a new monitor within

one of the three Cold Stores, a monitor in the Conservation Laboratory, and one housed within the Library Strong Room.

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 11th June to 14th June 2004, all of the monologs and the two Thermohygrographs were placed within an empty void, behind the sealed mahogany doors in one of the museum cabinets. Please note that two of the monitors from the Conservation Laboratory and the Library Strong Room were not included during this calibration period, as these were obtained during November 2004. The advantage of this location was that any fluctuations from the museum should not be recorded within the void, due to the excellent buffering properties of the museum cabinets.

The raw data was downloaded from the monologs, whilst the data from the Thermohygrographs was manually extracted. These were then tabulated into excel and graphed. (See Figure1)

The layout of the graph is as follows; the temperature readings are situated 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, even though all the monitors are within the acceptable ranges there are noticeable variations between some of the monitors.

This pattern is also mirrored for the humidity values. All of the monitors are within the recommended range; except for the monitor usually within the core store main corridor, which is showing lower readings. All of the values are constant except for certain variations recorded on some of the monitors.

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

Using the six new monitors purchased in June 2004; which should be the most accurate, the calibration factor was based on data from these, as 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 2 summaries the calibration values.

Logger No	Logger Name	Av. Temperature	Adjustment	Av. Humidity	Adjustment
0112-096	Beside Magnetic Tapes	19.4	Nil	43.1	+ 4.3%
" "	Core Store Main Corridor				
" "	Museum Library				
0109-595	Core Store Extension	19.4	Nil	47.2	+ 0.2%
0109-597	Pallet Store	19.3	+ 0.1 C	47.7	- 0.3%
0112-066	Tray Store	19.4	Nil	45.1	+ 2.3%
n/a	Museum Hygrograph	16.9	+ 2.5 C	52.4	- 5.0%
n/a	Core Store Hygrograph	17.7	+ 1.7 C	51.1	- 3.7%
Average calibration temperature & humidity based on 6 new monitors installed @ 11 June - 14 June 2004					
0407-204	Cold Store				
0407-196	NGRC Aisle 17, Box G239				
0407-217	NGRC Aisle 67	19.4 C		47.4%	
0407-219	NGRC Strong Room				
0407-210	Museum 1st Floor				
0407-213	Museum Ground Floor				

Table 2: 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.

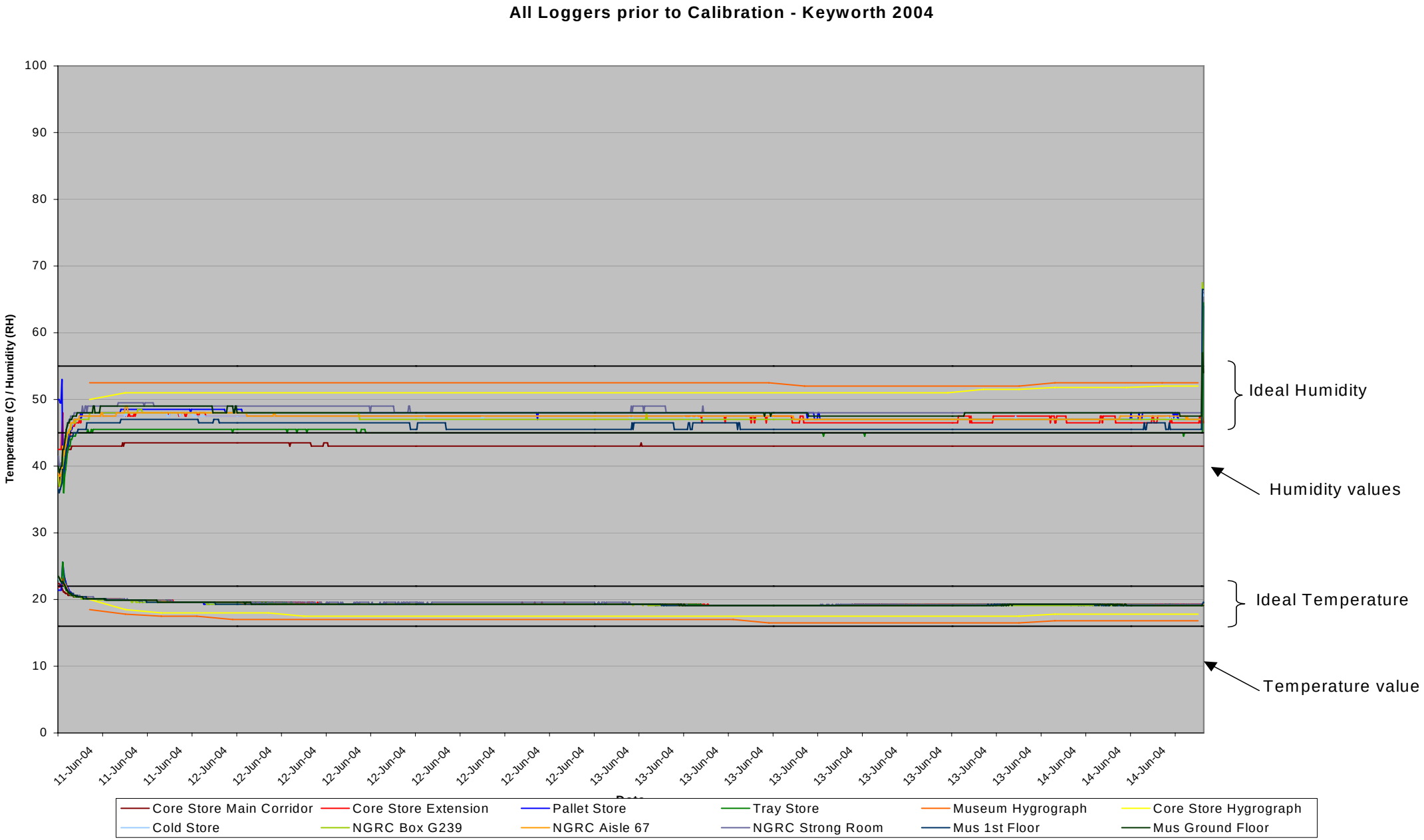

Figure 1: All Loggers prior to Calibration Period - Keyworth 2004

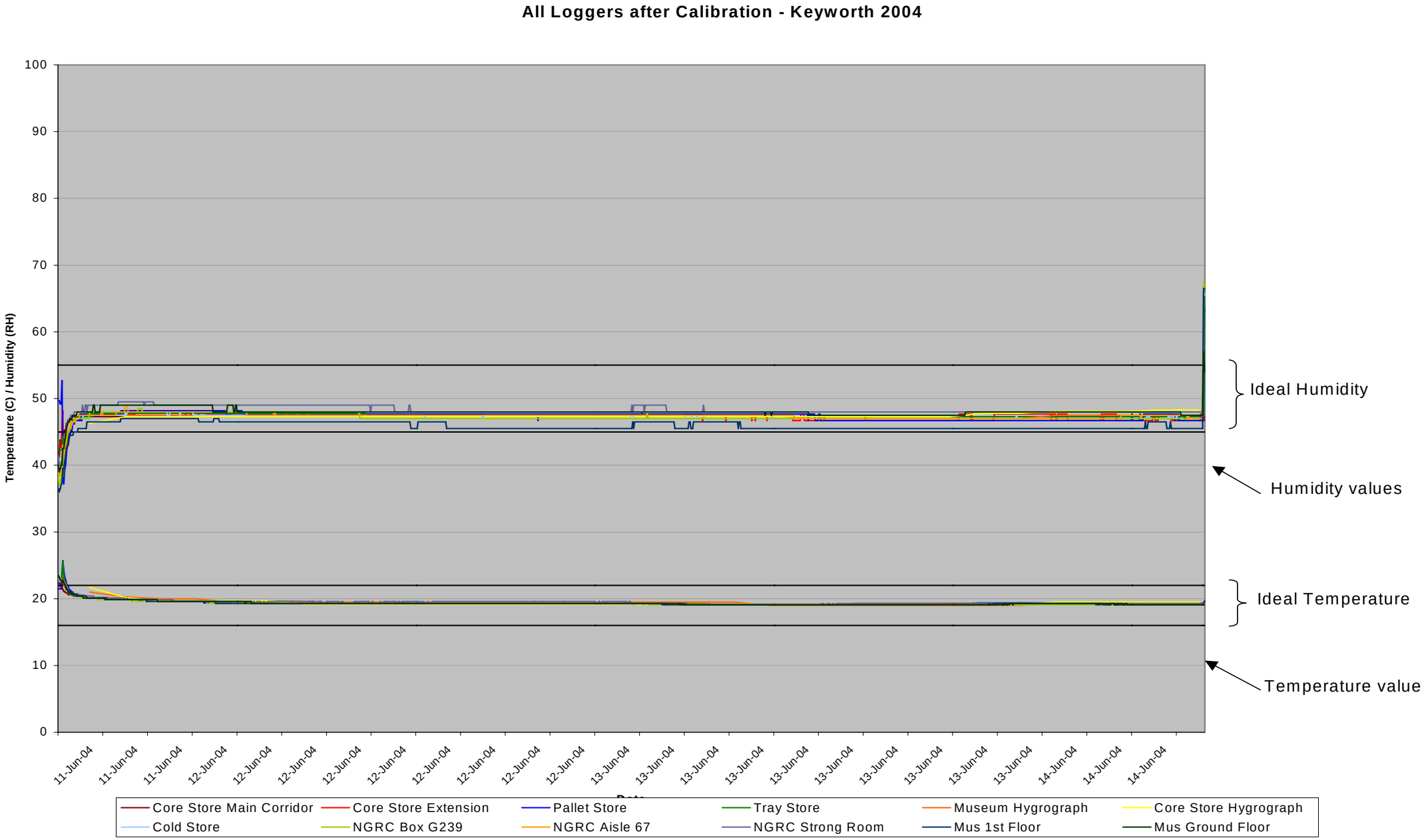

Figure 2: All Loggers after Calibration Period - Keyworth 2004

2.1.2 Calibration Summary

From the calibration period this year, variations in temperature and humidity still exist between the monitors, especially ones of the same types, even though they were situated in the same location. The adjustments made were small, considering that all the monitors were within the acceptable parameters during that time. Additionally these alterations are comparable to those made during last years report.

This justifies why the environmental monitors should be calibrated together 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 may not be as accurate as re-calibrations carried out by the manufacture. However the cost involved in re-calibrating them, 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 had to be converted into a GMT format as the monologgers had been downloaded from a laptop computer, which took into account daylight saving hours or BST (British Summer Time).

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 new 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 2004

As with previous years, 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 three years.

Three monologgers are situated within the Core Store, which in turn 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 during 2002-2003, a logger had been placed at the end of the first fully filled rack. This was situated next to metal horizontal racking plate, which in turn could affect the temperature readings, and thus the humidity. For 2004, it was decided that the monitor should be moved further away from this plate. It is now positioned on the same racking, at the same elevation but 4.5 metres away from the metal plate.

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 at three-minute intervals, recording any sudden changes in temperature and humidity.

Thermohygrographs are located in the main area of the core store at ground level and on the ground floor of the museum respectively.

The Casella 500+, which was located on the top floor of the museum, has now been made redundant as this was previously only monitoring temperature readings. It has been replaced in the same locality with a monologger, as of August 2004.

This chapter (2.3) will discuss the results for 2004 and will also make comparisons with the annual readings from 2003. 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 2004 has been produced for all the main loggers used in 2003, (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 major fluctuations in humidity throughout 2004, with all monitors showing a similar progressive pattern. There are also some noticeable variations in temperature readings, these are not as pronounced as the humidity values, but on a few short occasions most of the readings are outside the recommended temperature parameters.

For about 60% of the time from January through to late February, the humidity readings are within the acceptable range of 45 – 55%. However for the remainder of that period, the readings seem to be either noticeable higher or lower than 55 or 45% respectively. On one occasion all the monitors seem to record a dramatic increase in humidity values over a four-day period between the 29th January and 1st February, where the values rise on average by 30%. However no reason for this can be seen from external temperature and humidity readings taken during this period.

Throughout the rest the of February until the beginning of March, all the monitors show humidity values which gradually decreasing from the 45% mark to values around 20% humidity. Over this period, the museum hygrograph is recording the lowest values, whilst the core store extension is showing the higher readings.

From March to the end of April, the humidity readings appear to rise slowly towards an acceptable value. Exceptions to this are when the tray store monitor shows lower readings than those from other monitors around the 8th April. If the humidity readings from the museum hygrograph where inaccurate at the end of January, then they would have shown to have the lowest readings around the 8th April. However, this is not the case, the fact is that the museum hygrograph humidity values from 8th April, to the end of the year appear to be one of the highest for all the existing monitors.

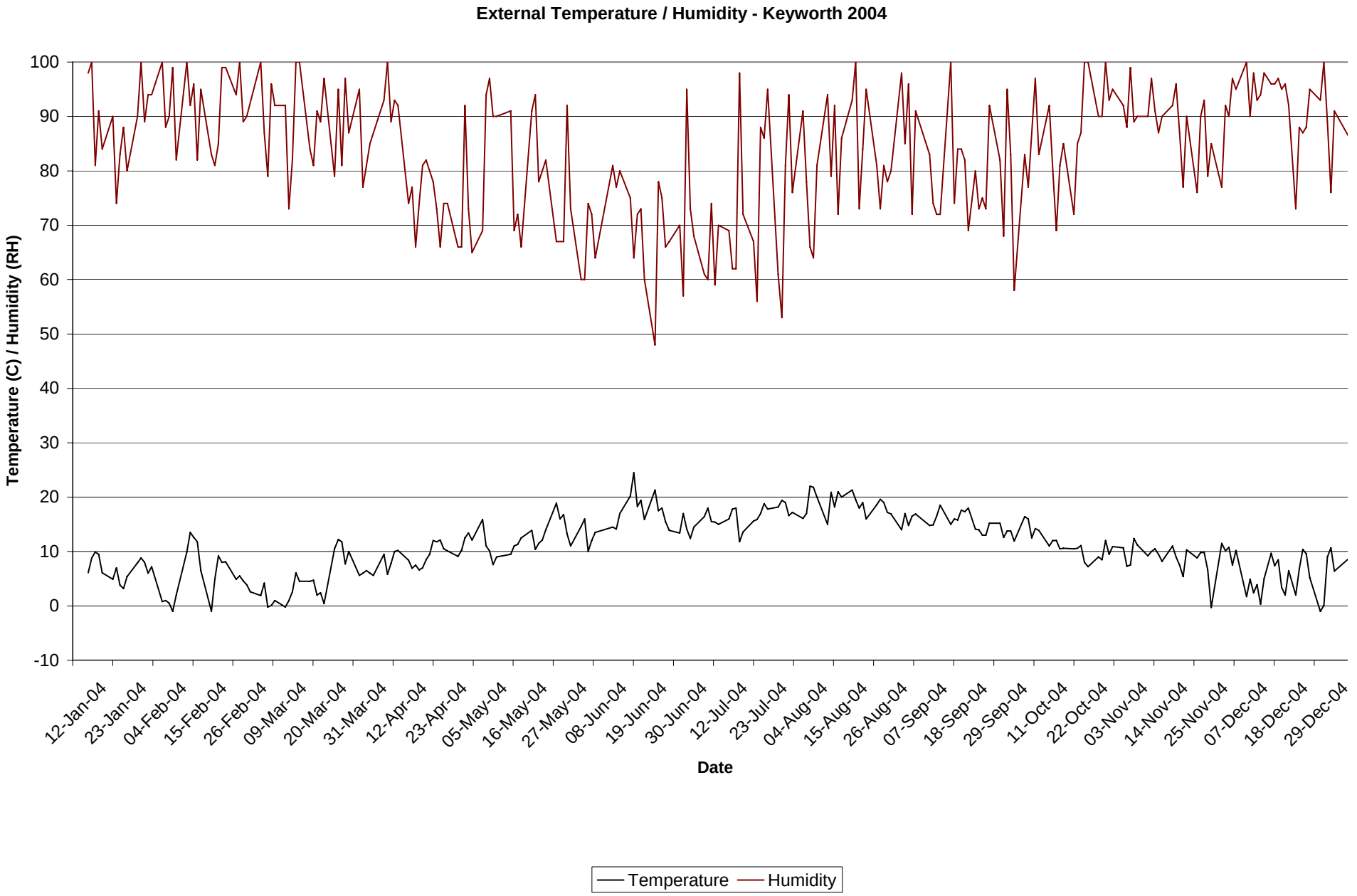

Figure 3: External Temperature / Humidity - Keyworth 2004

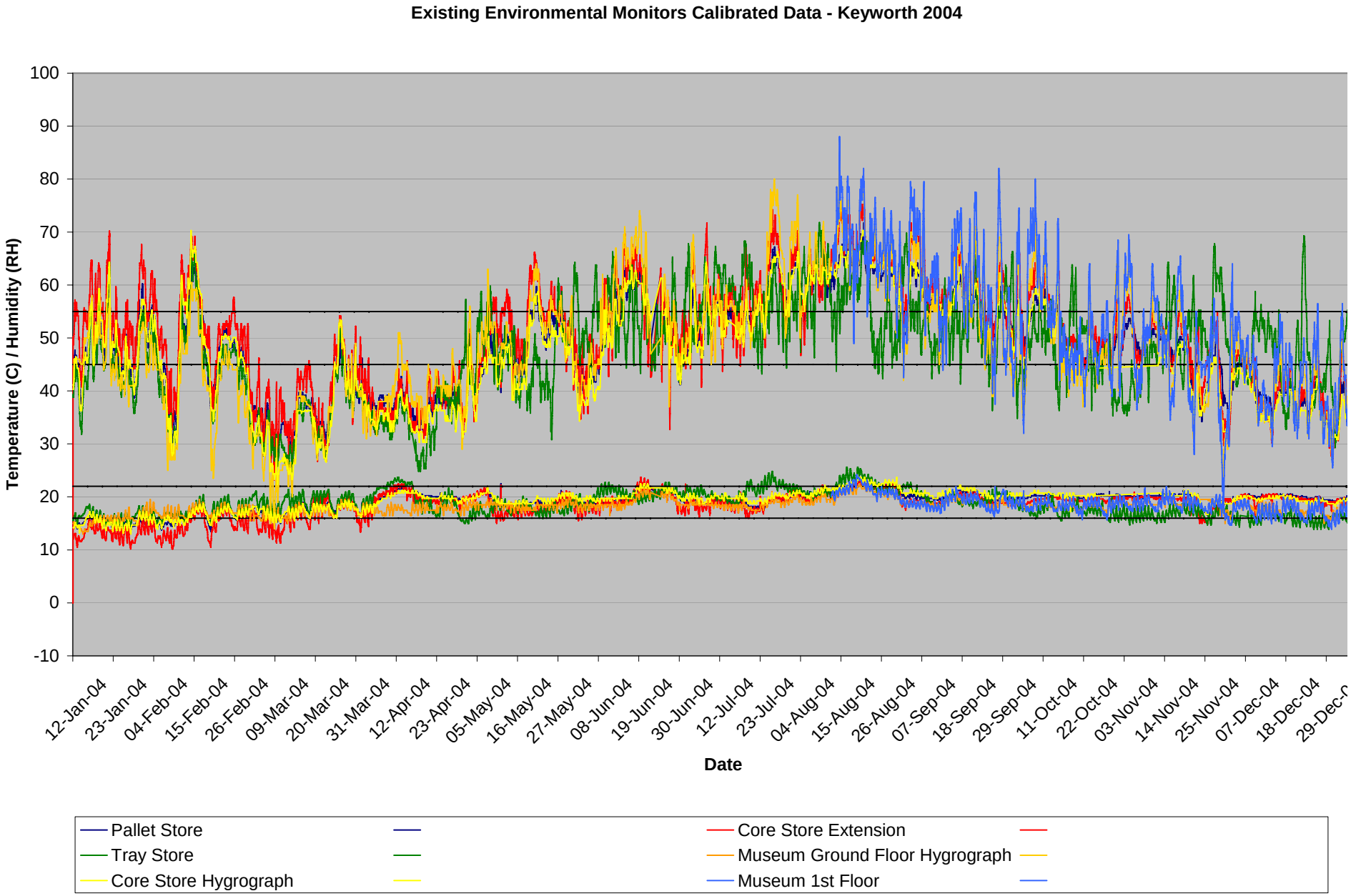

Figure 4: Yearly readings from Existing Environmental Monitors - Keyworth 2004

From May through to the beginning of July, there is a trend, where all the monitors display an increase in humidity readings towards ideal range, however on occasions these values are exceeded significantly by some of the monitors, i.e. the museum hygrograph and the core store extension. Possibly following a period of wet weather and high humidity during the beginning of May.

Throughout the summer months from July to the end of August, all the monitors are showing the highest humidity values above the recommended parameters at around 60% and often exceeding 75%. Problem locations are the ground floor of the museum and the core store extension. This is until the new monitor on the first floor of the museum start recording at the beginning of August, which then displays the highest values. This does not help, as the monitor is located in the southwest corner of the museum. However with readings taken in this vicinity of the building, this gives us an indication as to the worst or highest readings within the museum for that time of year, which may enable us to assess any possible risk to the material held within this area.

Through September to the end of October, there is a gradual decline in humidity towards the 45–55% range, even though some extreme readings mask this. During this time, the monitor on the first floor of the museum is still showing the highest values, whilst the tray store monitor is showing the lowest reading compared to other the monitors. The high humidity readings on the museum first floor have probably been exasperated by the museum roof leaking in the northwest corner, during periods of heavy rain from September to November. This has since been repaired and tested, and to date no further leaks have been identified. Comparing this period, September to October, with the beginning of November until the end of the year, there are numerous occasions where most of the monitors record data below the 45% threshold. Where the tray store monitor previously showed low values, it is now producing one of the higher values during November and December. As for the monitor on the first floor of the museum, these readings are more consistent with the other locations. This shows that the leaking roof was a probable factor in the high humidity levels. One of last year's recommendations at Keyworth was to close the shutter doors to the core store extension during periods when it was not being used to maintain more stable conditions within these areas. From mid November, this request has been implemented, only due to health and safety implications of staff working alone in these areas. However such actions have not affected nor improved the conditions within the core store extension.

Temperature readings taken in January struggle to reach the minimum 16°C, required for general collections, except for the Museum ground floor, and the tray store. From February through to the beginning of July, all monitors display readings within the acceptable temperature parameters, except on a few occasions where they fall outside of the ideal 16-22°C range. It can be seen twice from July through to Mid August, that the readings from the monitor in the tray store monitor often exceed the 22°C threshold, reaching 24°C on both occasions, whilst the remaining monitors readings not exceeding 22°C. From mid August to the end of 2004, all of the monitors including the new monitor on the 1st floor of the museum are all showing values within the acceptable parameters, except for numerous occasions where the tray store monitor dips below 16°C by an average of 1°C.

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 both graphs, it can be seen that the external temperature is having an effect on the internal temperatures across all locations, during the beginning of the year, through to mid February. A rise in temperature is probably due to insulation and heating across the site. And thus reducing the effect of the colder temperatures recorded outside at 9:00 GMT. Throughout the rest of the year until late autumn, the outside temperature on occasion peaks to 24.5°C during June. This is not affecting the

internal temperatures, which generally stays within the 16-22°C parameter. After mid September, as external temperatures decrease, internal values do not track these in the same manner, but start to fall more gradually to around 19°C, within the recommended parameters.

The external humidity throughout the year appears to be affected by the external temperature, where the temperatures rise and the humidity begins to fall. This can be seen from May through to July. However, for the rest of the seasons (spring, early autumn and winter), the external temperatures fall, whilst the external humidity remains high. This is due to the high amounts of rainfall during July and August, which experienced 150% and 225% of expected rainfall for these months.

The internal humidity readings are not being affected by the external humidity, only during the summer months where high humidity readings are experienced outside, due to high amounts of rainfall. Due to the higher temperatures outside, and thus more uncomfortable conditions within, doors and windows would be opened, allowing air to circulate and the internal humidity to increase.

Using the graphs on figures 4 & 3, and figures 6 & 5, comparisons and trends can be made between all the monitors, with climatic readings for 2004 and 2003 respectively.

Comparing the internal temperature readings of 2004 with those of 2003, it can be seen that there is a very similar pattern between each year. Such similarities are even apparent during July and August, when slight but noticeable increases above 22°C have been recorded. Additionally the annual decrease in temperature readings towards the end of each year is visible. Such decreases below 16°C are more pronounced during the winter-spring period of 2004, compared to the autumn-winter period in 2003.

For the internal humidity readings any comparisons between both years are not as noticeable. The only ‘general’ trend is that a proportion of the winter months are significantly below the 45% threshold. Whilst during the summer months, both graphs show values within and often exceeding the recommended 55% upper limit. For the winter-spring period of 2004, the humidity levels are more frequently within the 45-55%, compared to 2003. During the summer-autumn months, all the monitors during 2004 spend a greater amount of time within the recommended parameters, compared to those within 2003, even though the readings do peak to higher levels. During 2004 and 2003, the core store extension monitor shows the highest humidity readings throughout the year, whilst lower readings are recorded within the tray store. A similar pattern can be noticed for these temperature readings. This shows the tray store to have the highest values and the core store extension the lowest.

When you compare the external readings for 2004 and 2003 (figures 3 and 5), there are slight temperature variations from one year to the next. There is definitely a similar pattern for both years. For example, the colder January-February readings are noticeable during both years. Similar fluctuations in temperature are recorded throughout the summer months, in both 2004 and 2003. Annual trends in external humidity readings occur for both years, where high humidity levels are present during the winter-spring, and then start to fall come the beginning of April. During the summer months there is also a similar trend for both years.

Overall, it can be seen that the higher regular humidity levels occur during the winter months, whilst outdoor temperatures are at their lowest. It must be remembered that these high humidity levels are also due to the wetter weather conditions experienced during those times of year. Except for some frequent rain showers experienced during the summer months. This produces a rise in humidity. The remainder of the summer, a pattern develops showing that when external temperatures rise, drying out the air, which in turn encourages humidity levels to fall. Unfortunately this principle cannot be applied throughout the year due to a varying climate. Other factors should be taken into account, such as precipitation, wind speed, wind direction and ground temperature etc.

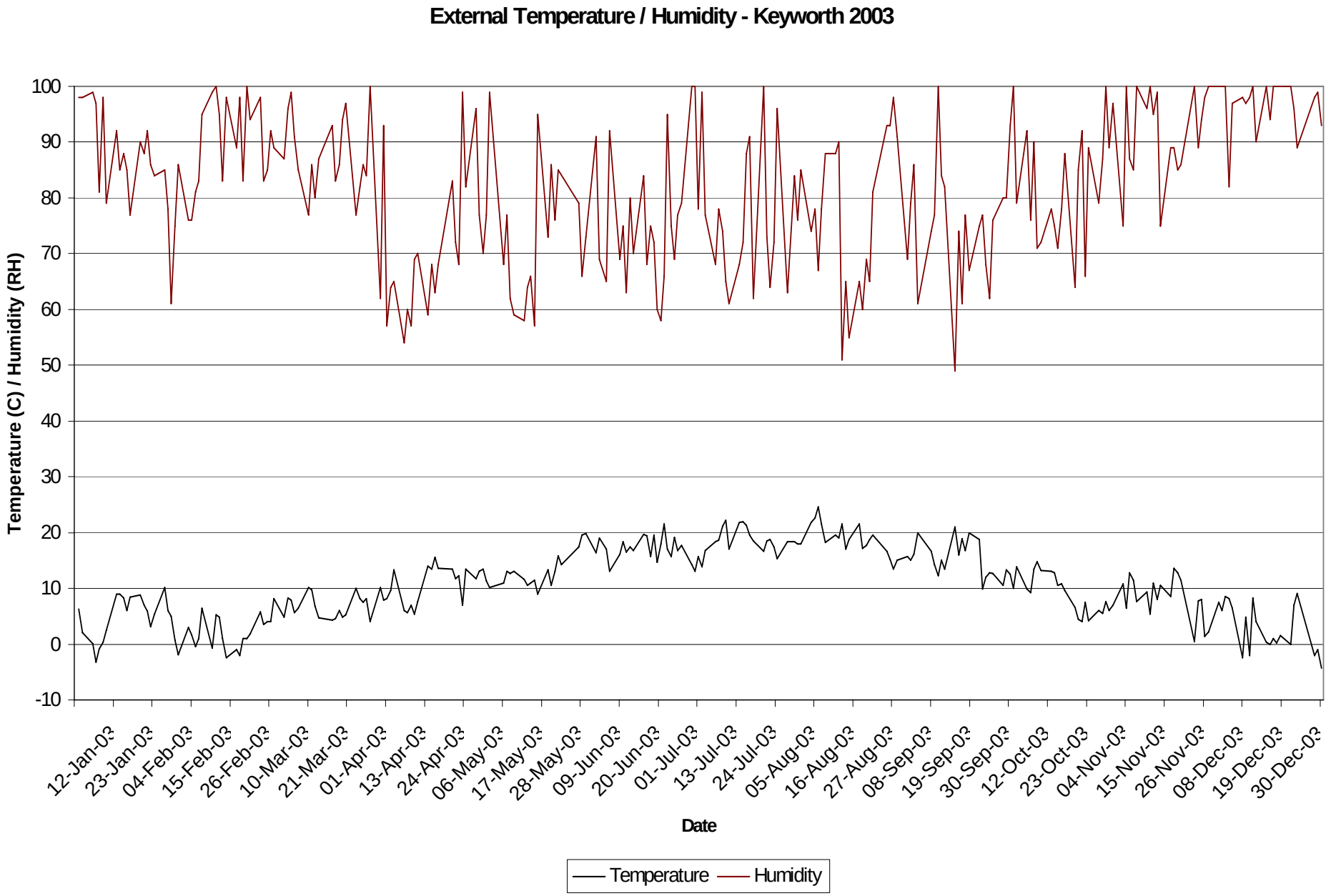

Figure 5: External Temperature and Humidity - Keyworth 2003

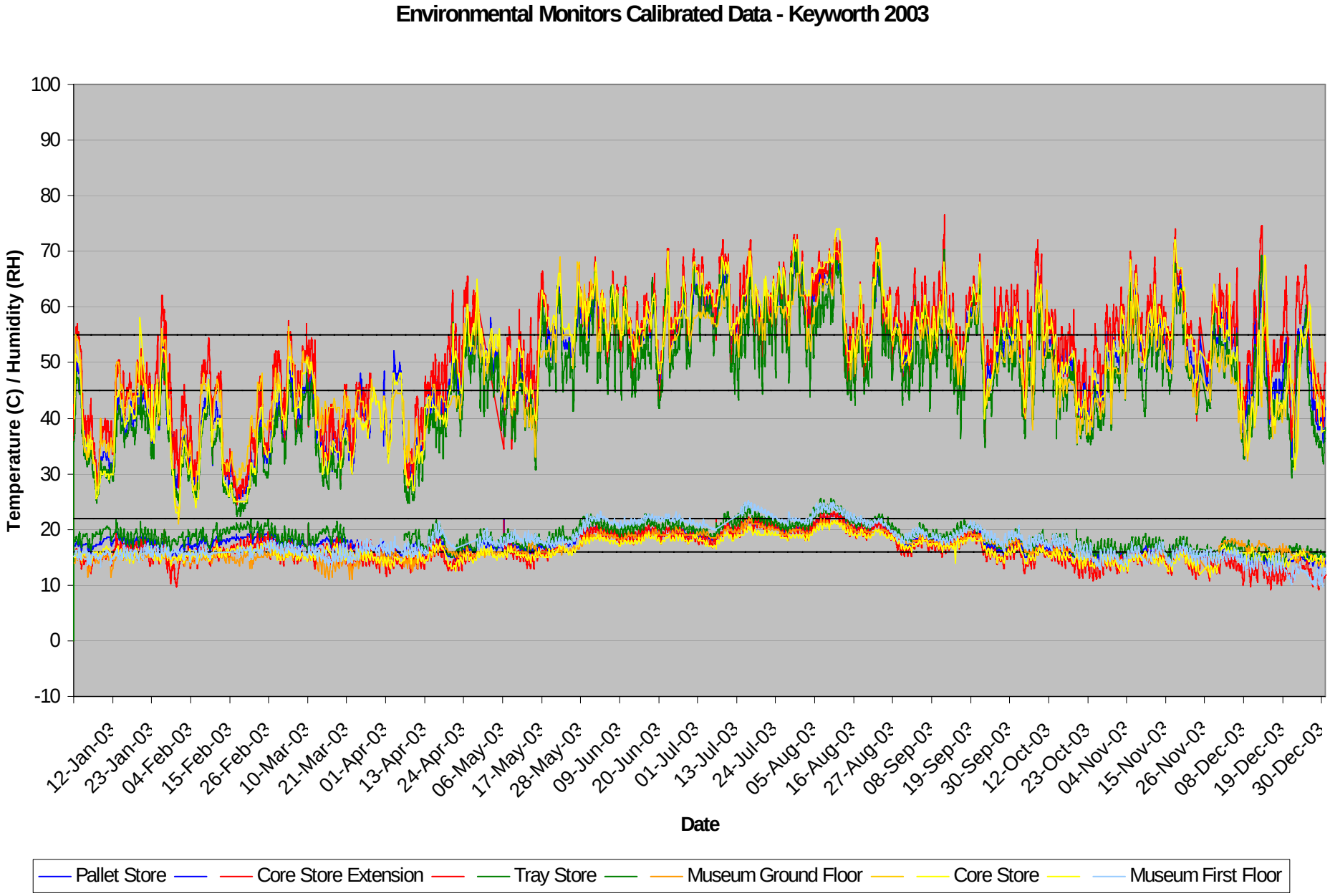

Figure 6: Yearly readings from Environmental Monitors - Keyworth 2003

2.3.1.1 YEARLY CALIBRATED RESULTS SUMMARY

Unfortunately over this reporting period there is very little change with the temperature and humidity levels for all the existing monitor locations. The only improvements have been where the humidity levels are generally higher at the beginning of the year compared to 2003. Additionally the humidity levels for the remainder of the year appear to fall within the recommended range more often than the previous year. A constructive observation is that the temperature readings for 2004 are within the 16-22°C parameters more often, thus showing a more stable environment. Comparisons between the meteorological readings are similar for each year, which might show why there are no major changes for 2004 and 2003 within each of the monitored locations. The more problematic locations appear to be the core store extension, with higher readings and the tray store with lower readings, however they do still follow the trends of the other monitors. Improving the environment within these large areas, i.e. the core store, core store extension and museum, can prove to be difficult. Due to their size, the cost of installing or upgrading existing heating / ventilation systems could be too costly, and would be disruptive to the collections, whilst work is carried out. During such periods the temperature and humidity would be affected until the systems are operational, and who's to say that improvements would make a dramatic difference in terms of the environmental conditions provided for the collections. It must be remembered that the majority of the collections are stored within microclimates i.e. wooden plastic trays and boxes. From last years mini projects the results have shown that these microclimates do buffer the effects of the surrounding environment in which they are stored.

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. This provides a clearer picture than line graphs, without the fluctuating values being displayed. Additionally these graphs show as a percentage, the 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 2004 as a percentage, whilst Figure 8 shows for comparisons the temperature readings during 2003.

During 2004, all the existing monitors are showing values where 80% of the time all the monitors are within the recommended 16-22°C. Compared to 2003 this is a significant improvement where values were only reaching 50%. During 2003, it was noted that the heating system to the museum was not functioning properly. This has since been rectified by Facilities Management, it is still being continually monitored on a regular basis as it is not fully effective, however the graphs show that there are noticeable improvements for 2004 within this area. The only monitor where there has been a decrease over the year, within the acceptable range, is the tray store, however this is only a 4% reduction. Obviously, if the amount of time within the recommended range has improved, then anything outside of this will have reduced compared to the previous year, these values now stand at below 15 %, compared to 47% in 2003.

Similar histograms show the humidity ranges for 2004 and 2003, see Figures 9 & 10 respectively. It must be noted that the museum first floor monitor was not recording relative humidity readings in 2003, so no comparisons can be made between that year and 2004. Although there isn't an improvement compared to the temperature readings, most of the monitors are consistent compared to 2003 readings. There has been a slight decrease in humidity, still falling within the recommended range for the core store, the tray store and the museum ground floor monitor, only by a maximum of 5.5%. Generally, there has been an increase in the readings below the 45% threshold, whilst the number of readings over 55% has fallen. This could be due to a slightly colder or prolonged winter this year and a marginally cooler summer compared to last year.

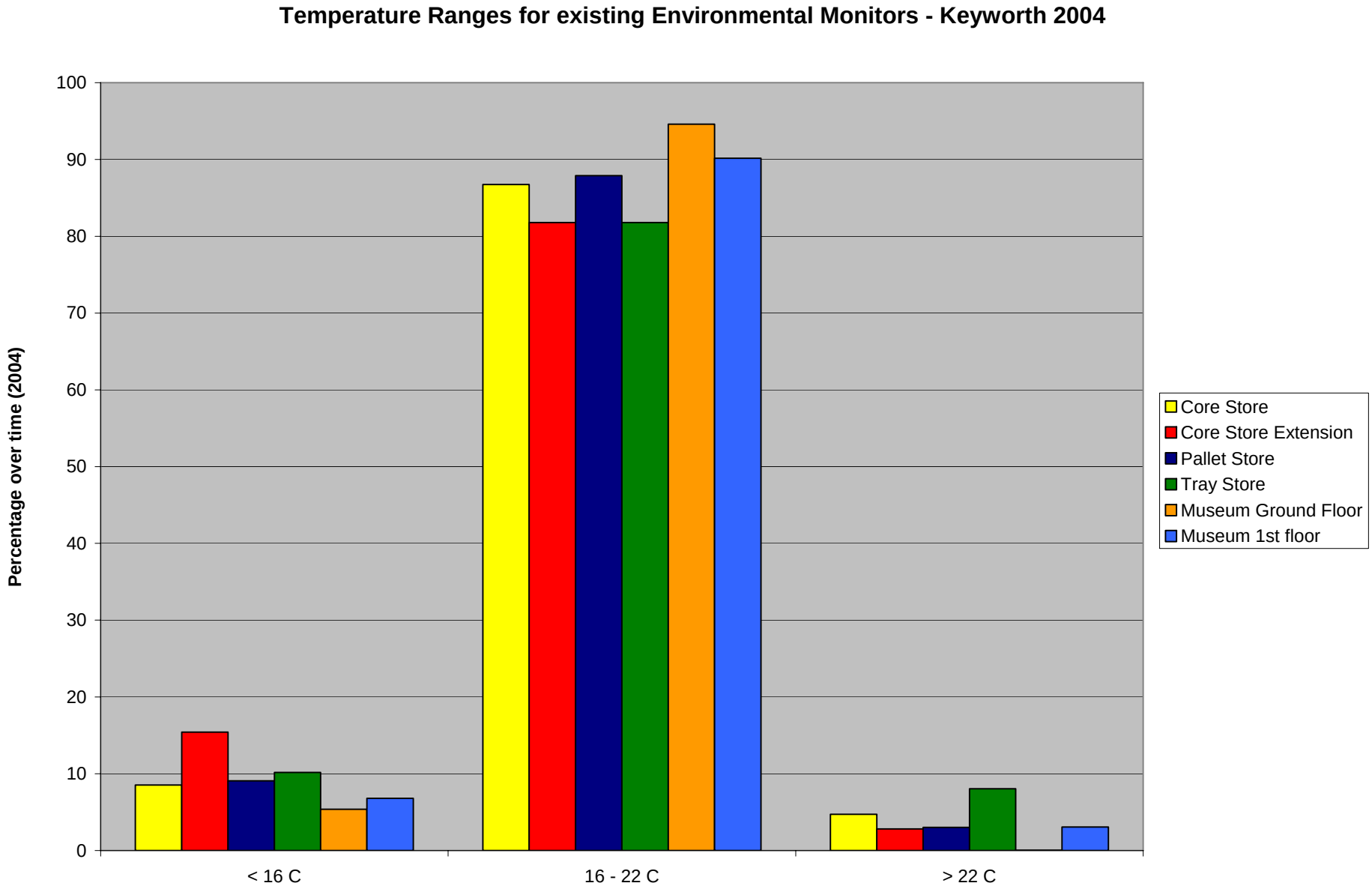

Figure 7: Histogram: Temperature ranges for all existing monitors – Keyworth 2004

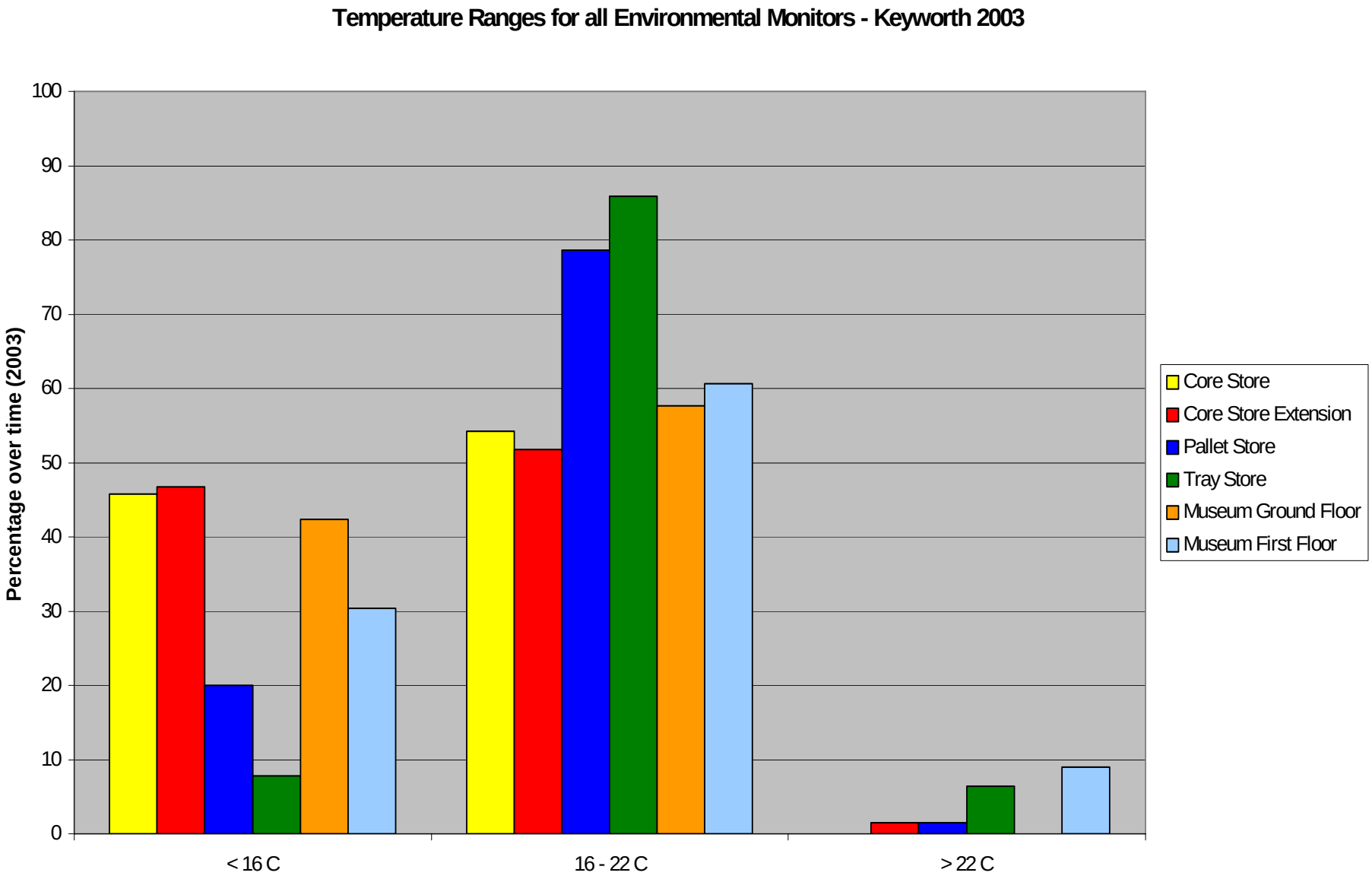

Figure 8: Histogram: Temperature ranges for all existing monitors – Keyworth 2003

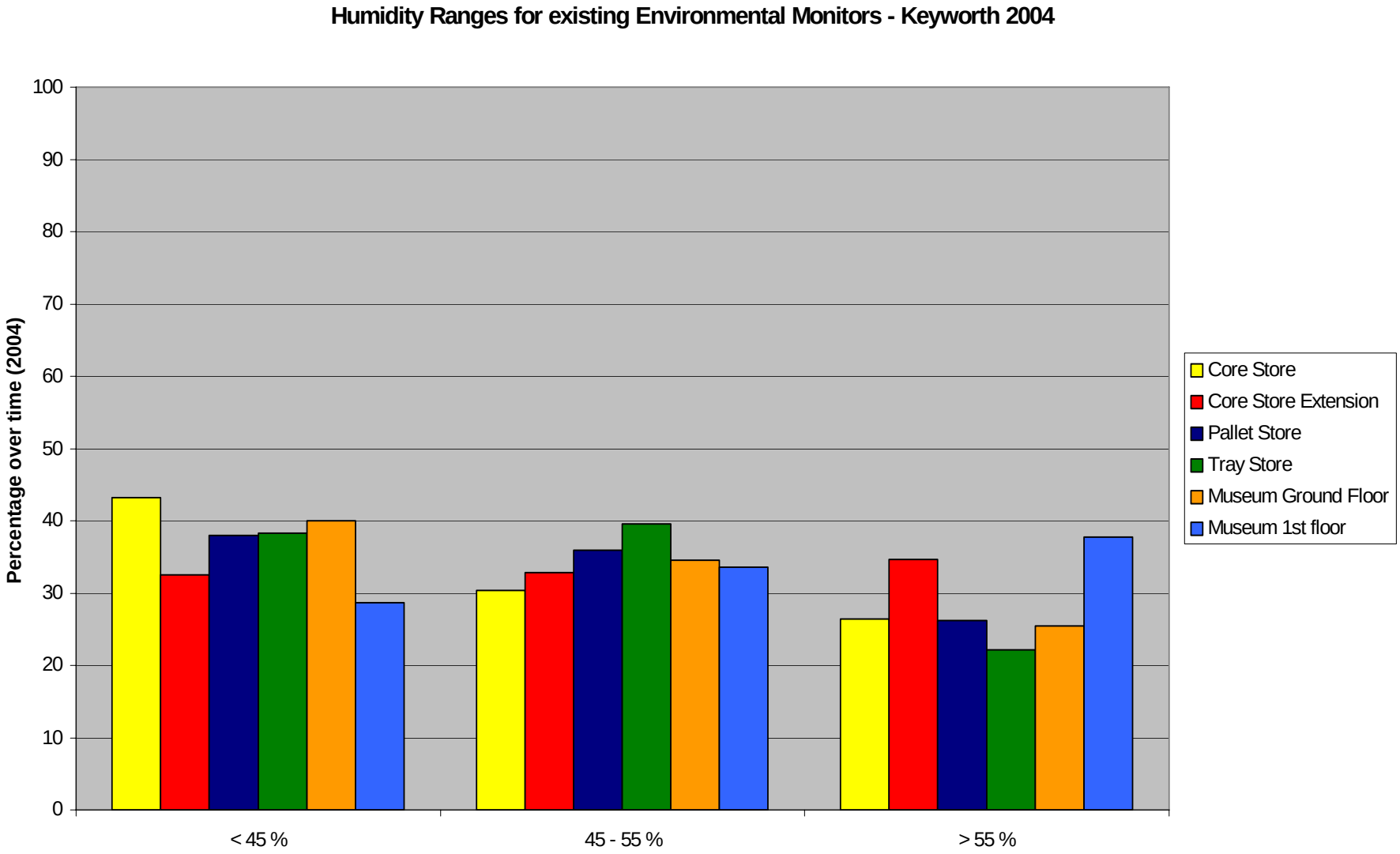

Figure 9: Histogram: Humidity ranges for existing Environmental Monitors – Keyworth 2004

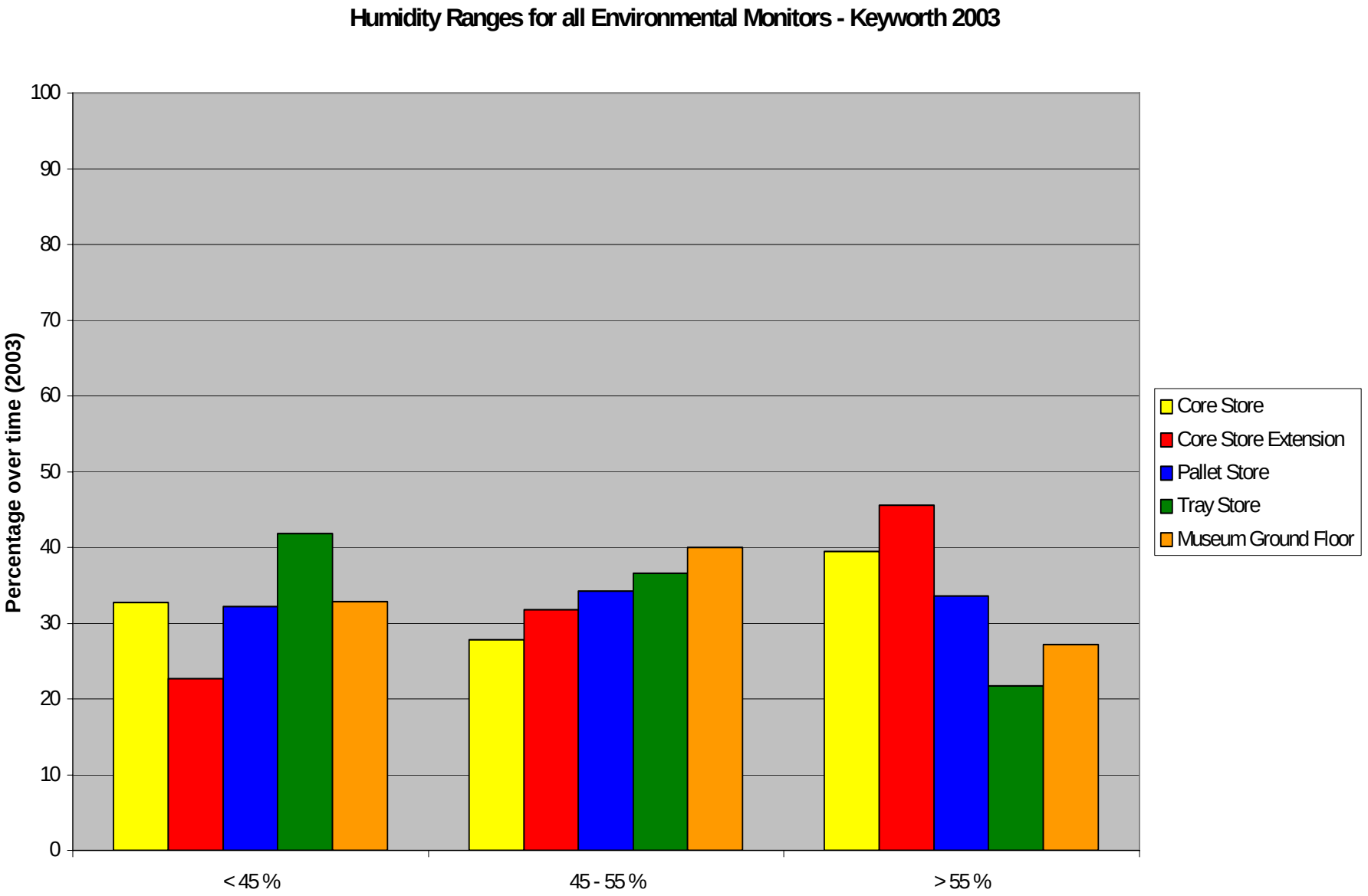

Figure 10: Histogram: Humidity ranges for all Environmental Monitors – Keyworth 2003

2.4 ADDITIONAL MONITORS WITHIN THE CORE STORE AREAS 2004

During 2004 funding become available to purchase additional Digitron Monologgers. It was decided to expand the monitoring programme within the core store on a permanent basis, rather than setting up mini projects like during 2002-2003, and to phase out the use of mobile loggers where possible. From June 2004 additional monitors were placed within the cold store (No 2), the core store main corridor and the conservation laboratory. Each area together with results will be discussed within this chapter.

2.4.1 Magnetic Tapes within the Core store

Prior to the phasing out of the mobile loggers, short term monitoring was carried out in order to get an indication of the conditions in which additional material is being stored, such as magnetic tapes within the core store.

These magnetic tapes, are currently being stored on the second floor of the tray store, are in addition to the other types of material being stored within the tray store. They were stored there by SNS (System Network Support) and contain important data from the Coal Authority. Each tape is placed within a sealed plastic case, in open planned racking, on a specially built mezzanine floor on the second floor of the tray store. Some 12,000 of these tapes have already been sent away to be transferred onto CD. However the rest remain here until funding is available to complete this transfer process.

Plate 1: Magnetic Tapes within Core Store

It was decided to monitor the conditions in which these magnetic tapes were being stored, as the surrounding material within the core store requires different recommended temperature and humidity levels. According to Table 1, the ambient temperature and humidity for modern records such as magnetic tape should be around 18-22°C and 35-45% respectively. The monitoring period took place for about a month and a half from the 2nd March until 19th April

2.4.1.1 MAGNETIC TAPES WITHIN THE CORE STORE RESULTS

From Figure 11, it can be seen that the temperature next to the magnetic tapes on the second floor of the core store (red line), varies throughout this monitoring period, and occasionally fall below the minimum recommendation of 18°C. Using figures 11 - 12, which also plot the data from other levels of the core store i.e. the core store Hygrograph (ground floor), and the tray store (fourth floor). This shows that for 80% of the time during this monitoring period, the

second floor next to the magnetic tapes is within the recommended 18-22°C range, compared to 74% for the core store hygrograph and 49% for the tray store monitor.

Using figures 11 and 13, the humidity fluctuates within and either side of the recommended range, however a similar pattern is also noticed on the other two floors within core store. The results are quite pleasing from the humidity histogram, as the tapes current storage location is within the 35-45 % range for 82% of the time, compared to 27 and 28% for the other floors. Whilst the percentage of time over 45% is only 5% compared to 57% on the ground floor of the core store.

2.4.1.2 Magnetic Tapes within the Core Store Summary

In summary, even though this area is not a purpose built for this type of material, it can be seen that the current location within the tray store is very acceptable. Comparisons between this floor and other levels within the core store show that this floor is the most suitable. It must be remembered that the results over this short period are encouraging, however over a longer monitoring period we could ascertain if this remains the case over a full monitoring year, thus giving us more accurate data on the conditions of the long-term storage of these magnetic tapes.

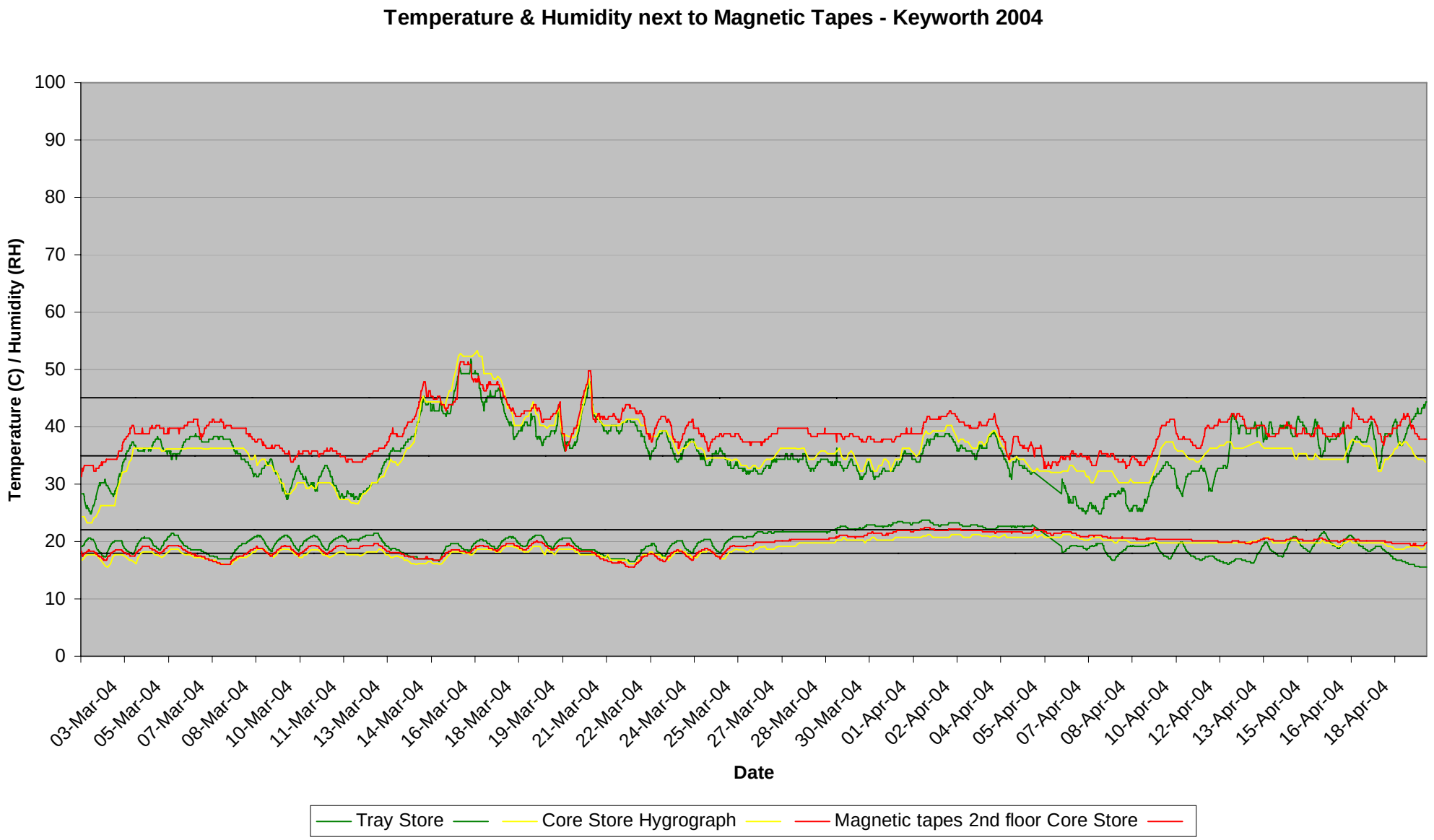

Figure 11: Temperature and humidity levels next to Magnetic Tapes within the Core Store

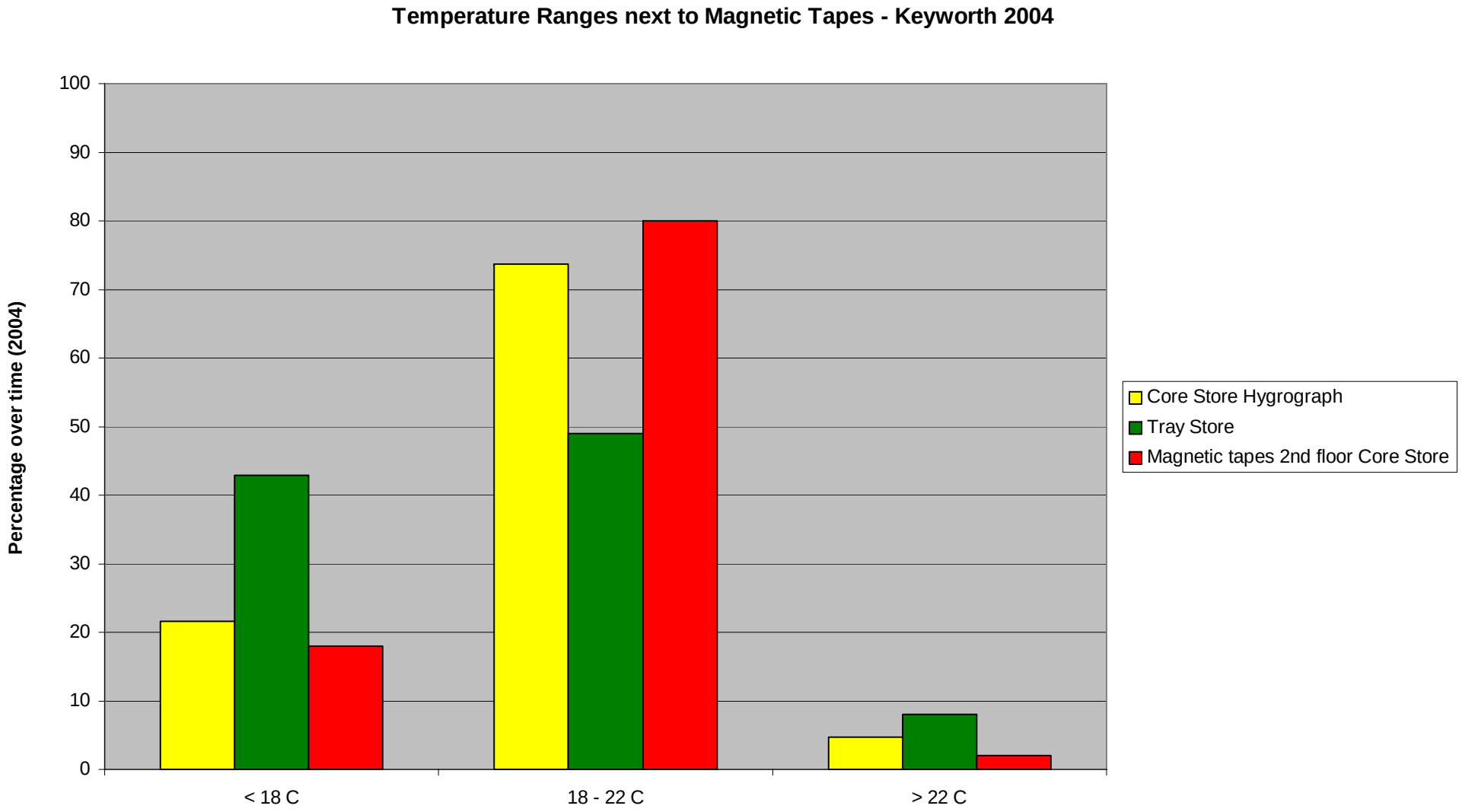

Figure 12: Histogram: Temperature ranges next to Magnetic Tapes

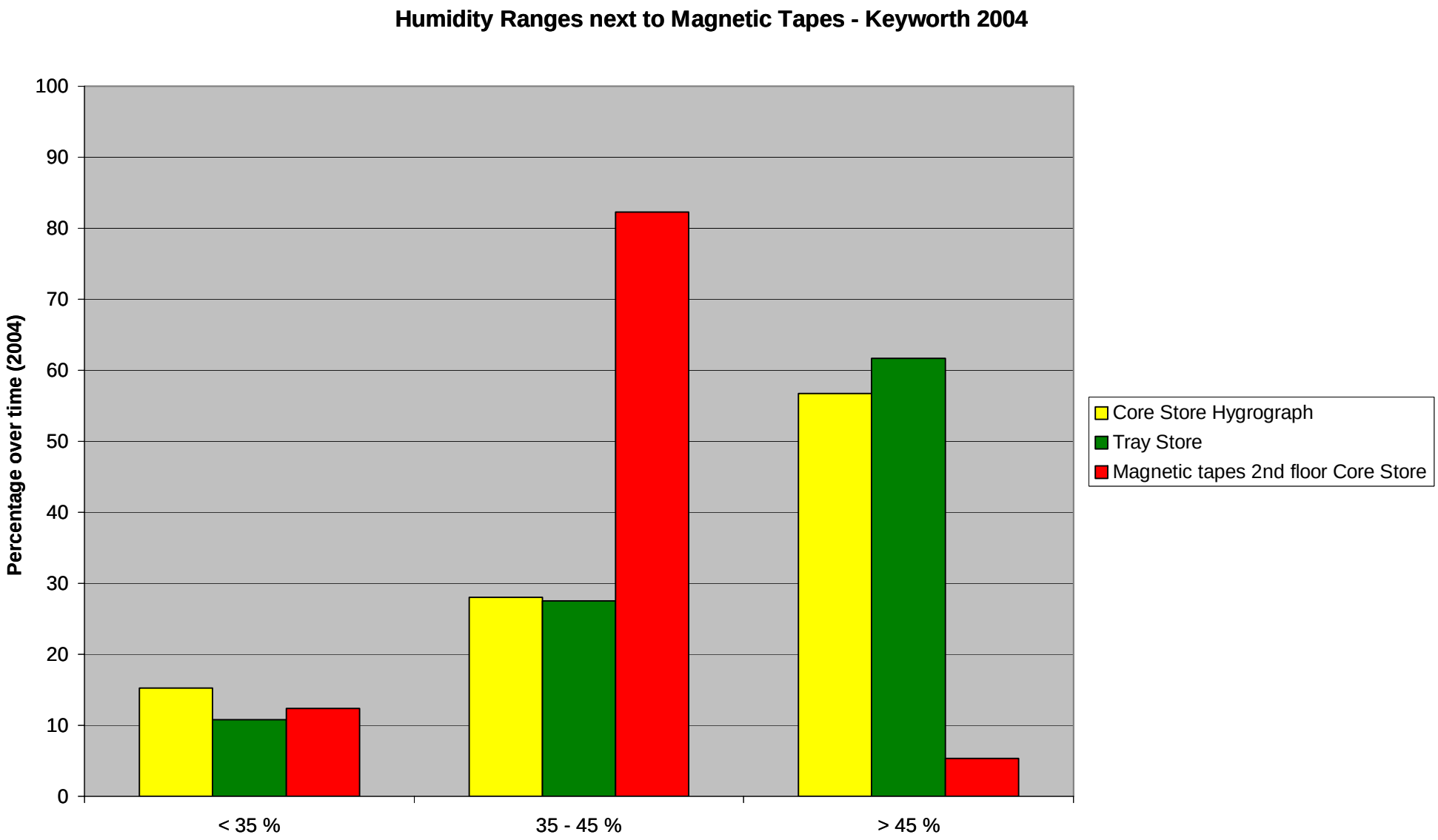

Figure 13: Histogram: Humidity ranges next to Magnetic Tapes

2.4.2 Conservation Laboratory & Core Store Main Corridor

The Conservation Laboratory contains a variety of specimens whilst the Conservator carries out the preservation work. Depending on the size of the specimen and the remedial conservation work required, it could be some time before the specimens are returned to its usual storage location. That is why it is important to monitor the temperature and humidity within this area.

Plate 2: Conservation Laboratory

Additionally, just outside the Conservation Laboratory is the main corridor of the core store. This is where for the majority of the time the three core store technician's work. Adjacent to this area are examination bays where material is putout for examination for staff and visitors. Within this area, boxes of core and other material are stored whilst waiting for the material to be sorted and curated. Member of staff use this corridor to get to the main core store, the pallet store and the core store extension. Forklift trucks use this corridor to transport material from the loading bay doors to the rear of the core store.

Plate 3: Core Store Main Corridor

Monitoring for the Conservation Laboratory commenced on the 9th November 2004, this is one of our newest monitors purchased in November, and thus was not included during the calibration period. As this monitor was recently supplied from the manufacture, it already should be accurately calibrated and thus should be giving similar readings to those monitors calibrated in house.

Within the main corridor of the core store, it was brought to my attention by the Core Store Manager, that this area was having problems with leaking underground hot water pipes.

Unfortunately the pipes run the length of the core store corridor, and are only accessed at intervals through metal grates in the floor. It was believed that this additional leaking hot water might cause an increase in humidity within the corridor. Readings commenced from the 2nd August 2004, using a mobile logger from last years report.

2.4.2.1 Conservation Laboratory & Core Store Main Corridor Results

A graph displaying the results for both the Laboratory and the main corridor is shown in Figure 14.

The monitor situated within the laboratory shows readings fluctuating regularly just above the 22°C, this appears to be almost on a weekly basis throughout the monitoring period. Where the more stable, (within 16-22°C) period occurs at the weekend, when the BGS site is closed to staff. These regular peaks in temperature are probably due to the laboratory being uses during the day, and regular use of the fume cupboards. For the same period, the humidity readings are erratic and well below the 45% humidity recommended for general collections. On numerous occasions this drops down to around 27% RH.

For the main corridor of the core store, the temperature is generally around the 22°C mark for this monitoring period. However through August this increases slightly, with a few high recordings being around 27°C. Since this monitor has been recording the humidity, the readings started off extremely high around 65-70%, from August through to October. This has then gradually decreased to an average of 37% by the end of the year. This reduction in humidity is likely to have resulted from the maintenance work being carried out to repair the hot water pipes, rather than the high external humidity levels penetrating into the building. As it can be shown that during the winter months, the external humidity levels are still high, however this is not represented internally during that same period.

There were concerns that the humidity readings within the conservation laboratory were inaccurate, but from this graph, it can be clearly seen that this is not the case. The humidity levels from the laboratory, mirror those of the corridor within the core store. This shows that the corridor monologger has been calibrated as accurately as possible ‘in house’, compared to the newly calibrated laboratory monitor by the manufacturers.

Using figures 15 and16, this five month monitoring period shows that the laboratory is only within the 16-22°C range for 40% of this time, compared to 58% for the main corridor. There are no readings below 16°C. However temperature readings greater than 22°C, in both the conservation laboratory and the core store main corridor are at 60% and 40% respectively.

The humidity readings show that the conservation laboratory is below 45% for this whole monitoring period, compared to 41% for the corridor. Whilst the main corridor is the only location where for 38% of the time readings are within the 45-55% recommended range.

2.4.2.2 Conservation Laboratory & Core Store Main Corridor Summary

Both areas show readings below the recommended parameters for during this monitoring period. It appears that the laboratory follows a similar pattern to the main corridor within the core store. The repairs on the leaking hot water pipes have seemingly been successful. Continual monitoring is required in these areas to give an overall picture for the year, before any additional action, if necessary is taken. Even with the extreme humidity values recorded, it must be remembered that material is stored within boxes and trays, and should reduce the effects of these fluctuating humidity levels. As the laboratory is a small confined room, it might be possible to try and increase the humidity within this area. This could be carried out by the use of a humidifier or by placing bowls of water near a heat source; this might increase the humidity levels. Such a trial experiment would need to be monitored to see if this effect was successful.

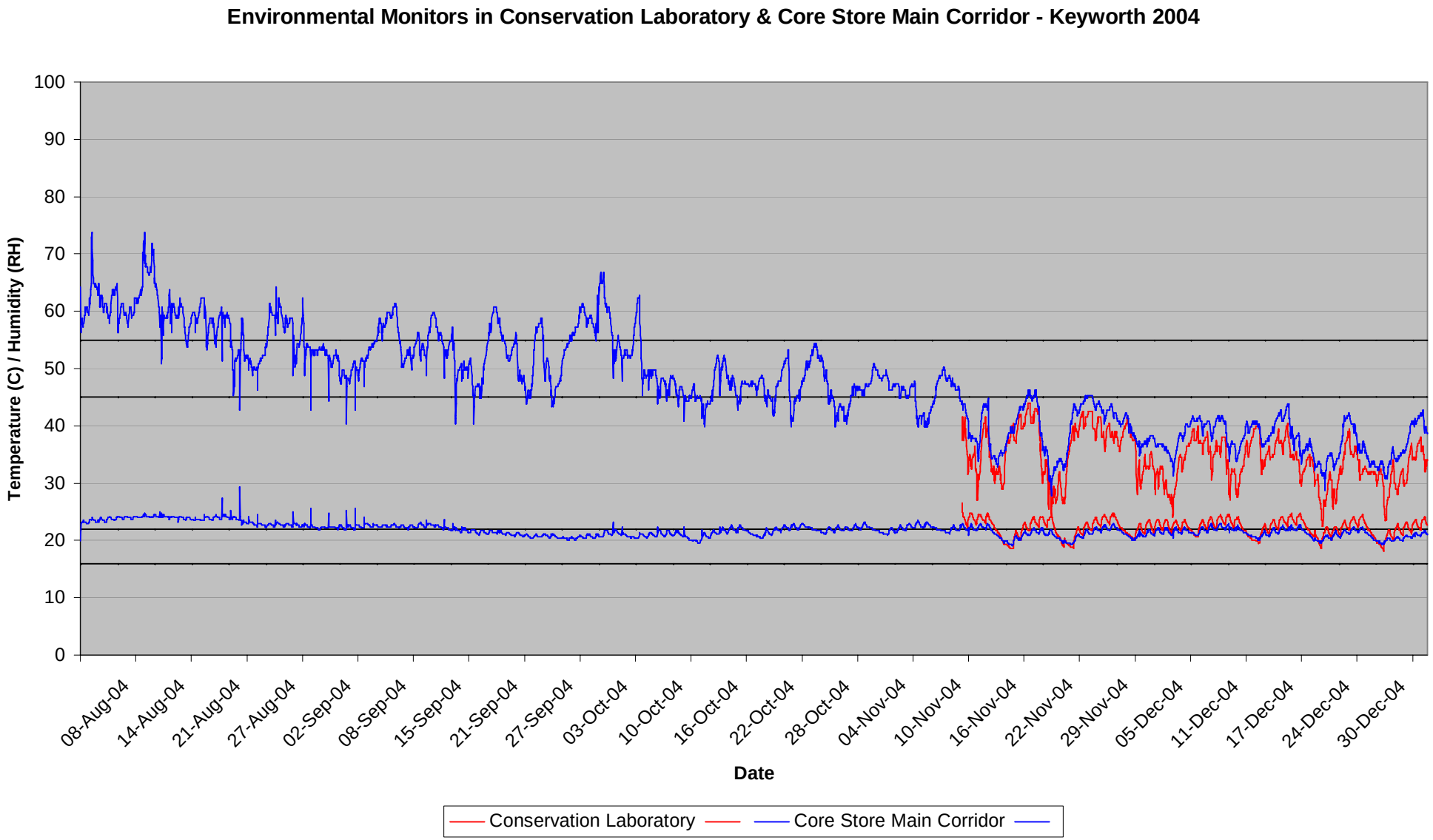

Figure 14: Temperature and humidity in the Conservation Laboratory & the Main Corridor of the Core Store

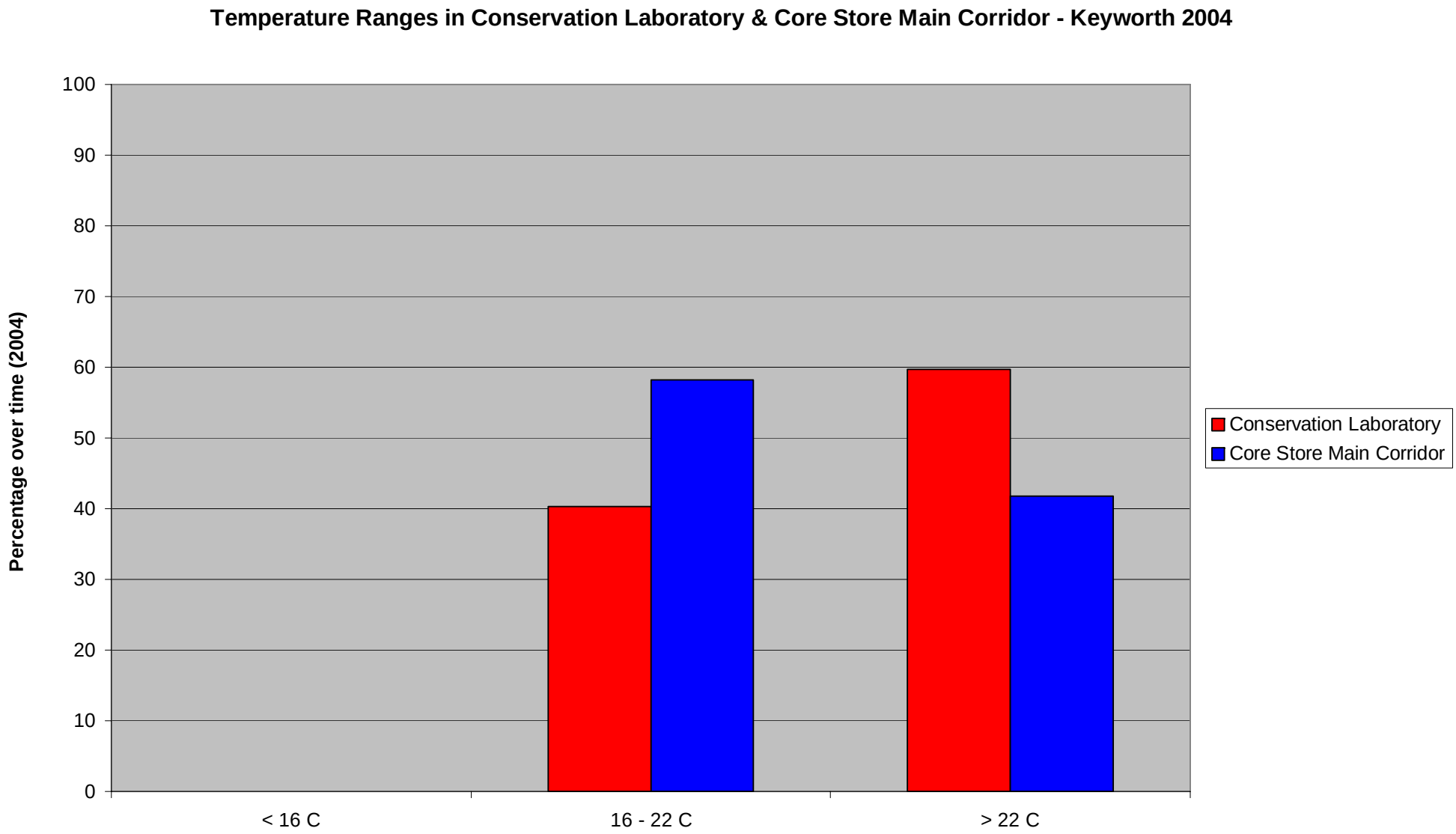

Figure 15: Histogram: Temperature ranges for the Conservation Laboratory & Core Store Main Corridor

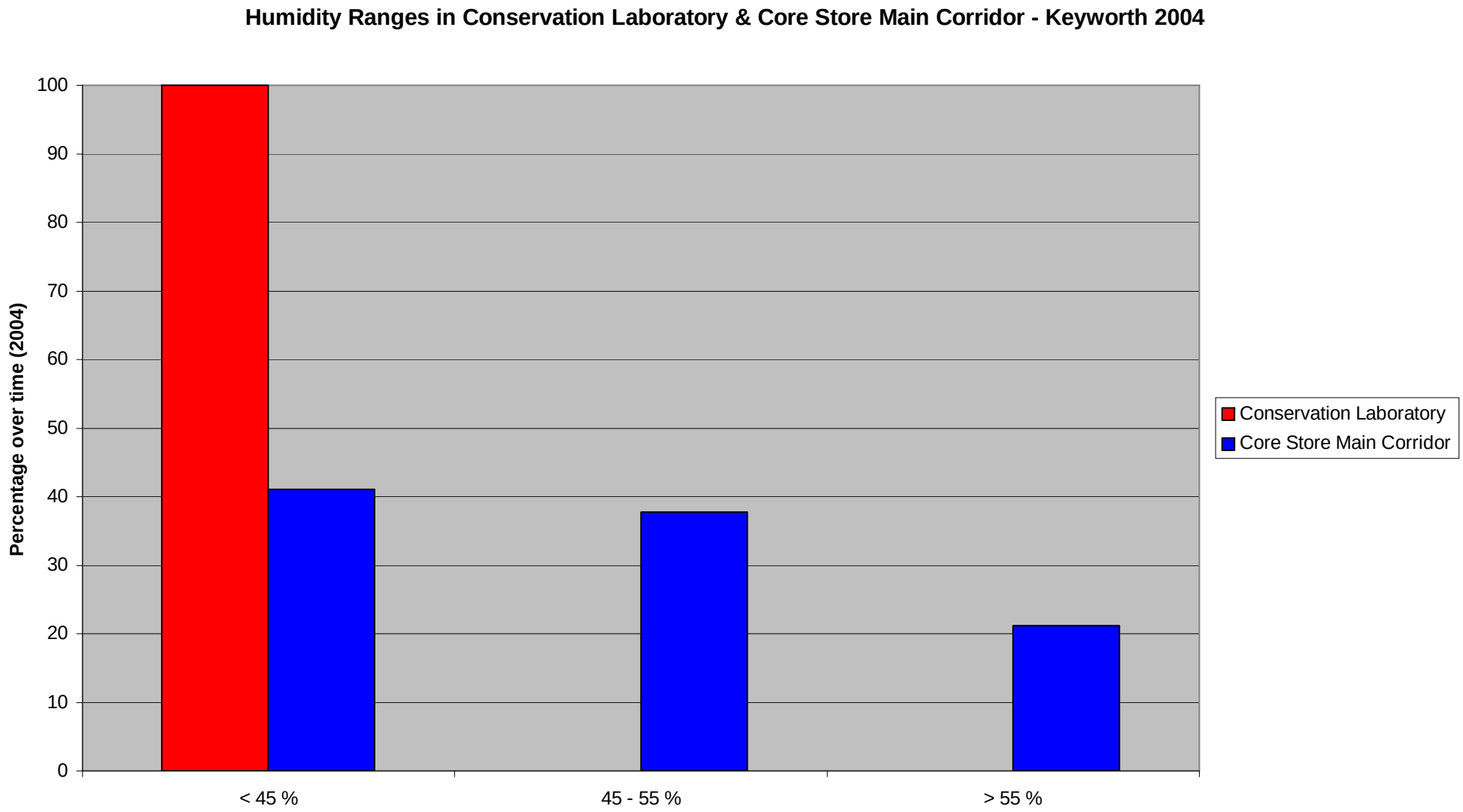

Figure 16: Histogram: Humidity ranges for the Conservation Laboratory & Core Store Main Corridor

2.4.3 Cold Stores

An additional area included within the monitoring programme was one of the three cold stores situated to the rear of the core store.

The NGRC Corporate Collections posses three cold stores which hold material for various units on site. Materials housed in these stores include water samples, soil and peat samples, 'waxed' core samples and unconsolidated core samples. Most material is stored on a project related temporary basis although some are stored on a 'permanent' basis.

The stores are keep at a temperature of 4^{o}C (+/- 2^{o}C) this is to inhibit the growth of bacteria within the samples. The cold stores temperature is regulated by a thermostat system, and is driven by large fans to the rear of the stores. Air is drawn in from the outside, but is first cooled, and then is distributed throughout the cold stores by additional fans.

Monitoring for cold store (No. 2) commenced on the 14th June, after the in-house calibration period.

Plate 4: Cold Store No. 2

2.4.3.1 Cold Store No. 2 Results

From figures 17 - 18, the graphs show that the temperature is within the recommended 4°C (+/- 2°C), for almost 94% of the time, even through the summer months. There were occasions where the power supply was disrupted for some periods of time, due to construction work being carried out on site. This together with the continual use of the cold store by staff has not affected the temperature of this storeroom. There are a few sudden changes through the year, which are due to staff accessing the material within the cold store. Even though the cold stores have no recommended storage humidity levels, it can be seen that they are constantly between 77% and 92% RH.

2.4.3.2 Cold Store No. 2 Summary

By monitoring one of these stores, this has given us an indication as to how these cold stores are responding. Over the monitoring period, it can be seen that this man-made environment has not been affected by the external climatic conditions or usage of the stores. This shows that materials within the cold stores are being stored within the correct recommended temperatures.

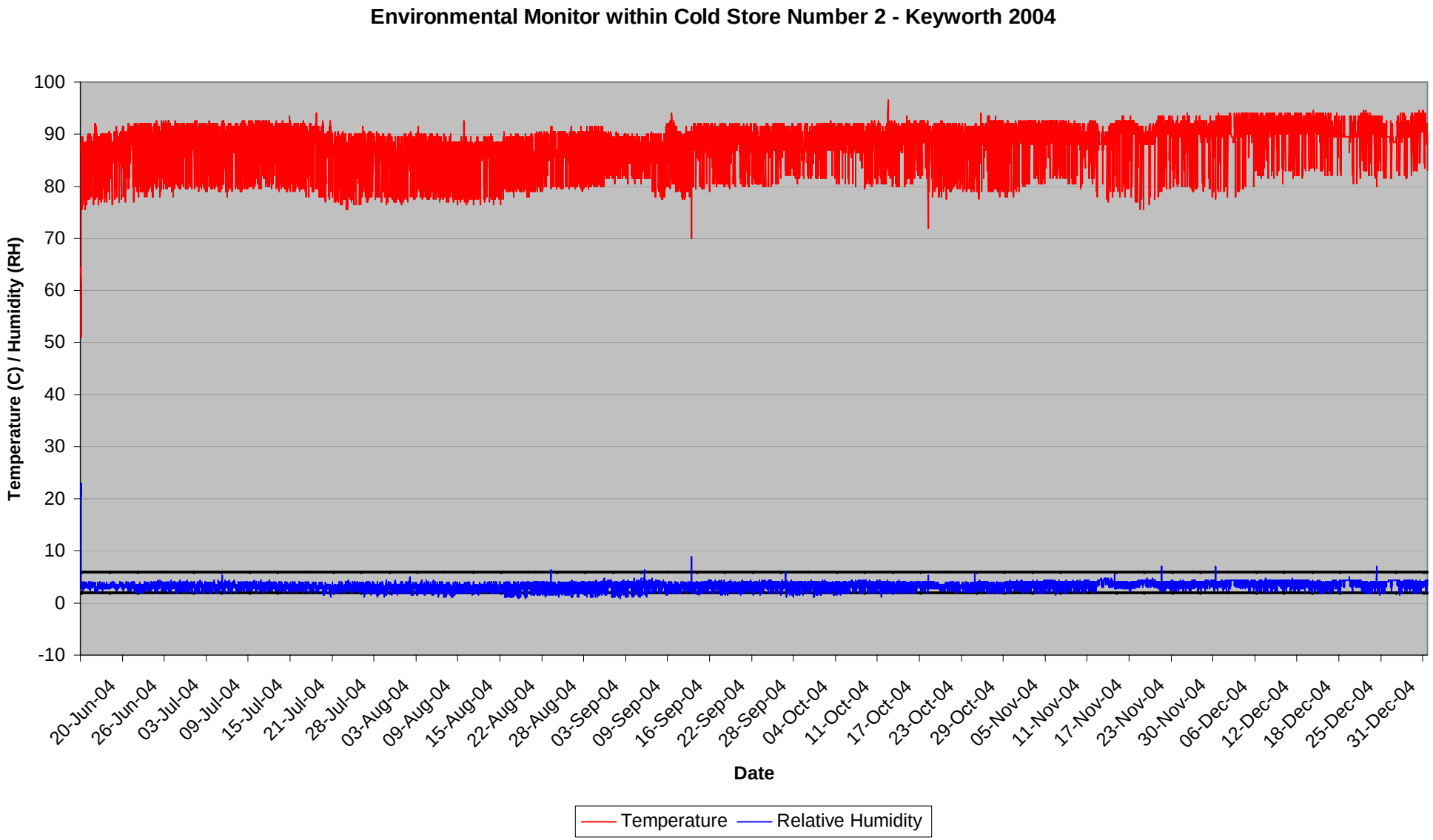

Figure 17: Temperature and humidity readings within Cold Store No. 2

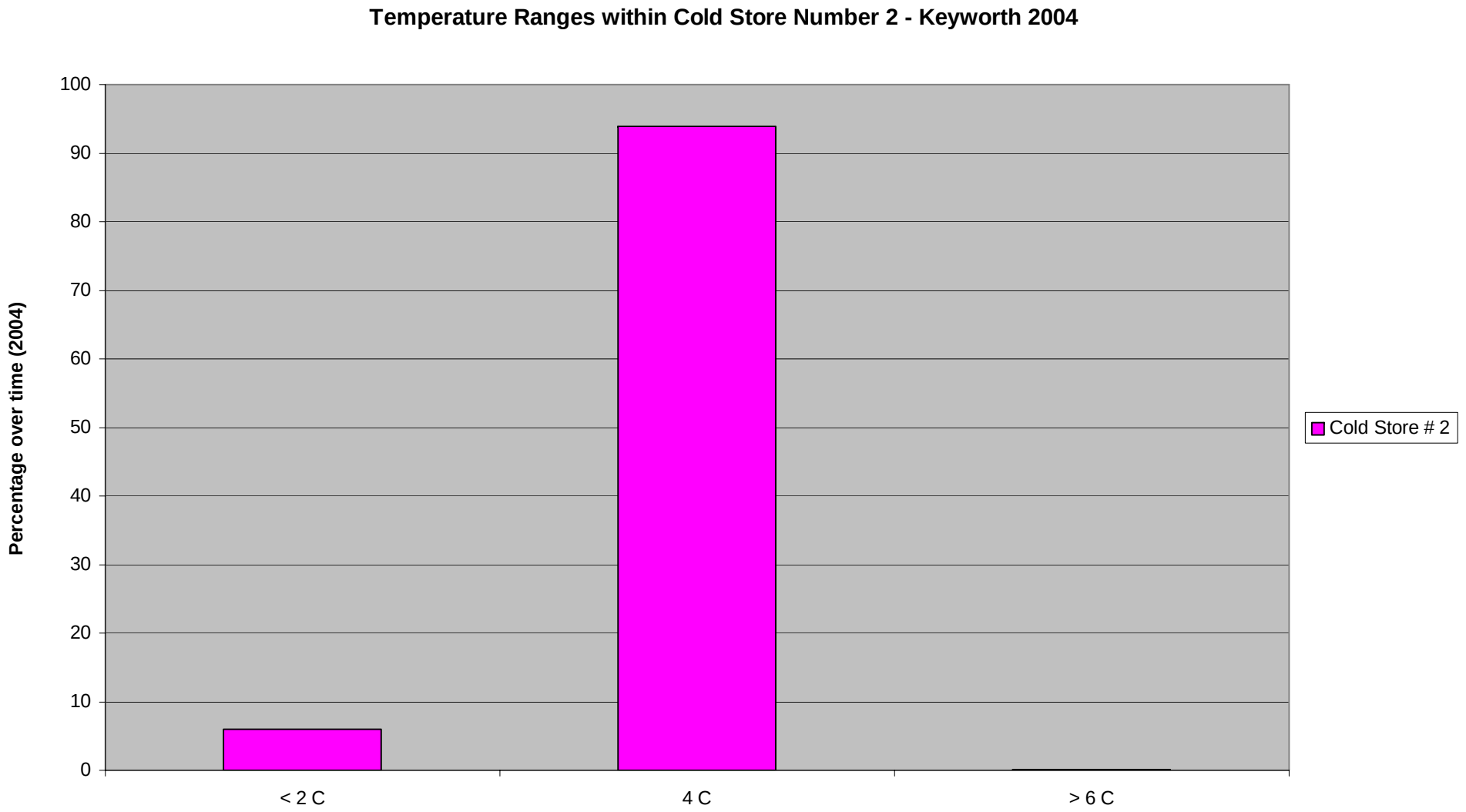

Figure 18: Histogram: Temperature ranges for the Cold Store No.2

2.4.4 Comparisons for all monitors within the Core Store Area

During this chapter, there have been so many different graphs for so many different areas; therefore it is hard to make general comparisons throughout the core store. This can be simplified using an additional graph, figure 19, which shows the amount of time within the associated recommended ranges, for all the localities. Please note that some of the locations were over a shorter time period than the remainder.

2.4.4.1 Comparisons for all Monitors within the Core Store Area discussion

From figure 19, this shows that the temperature in most the areas where within there individual recommended ranges for at least 80% of the time. This however does not apply to the conservation laboratory or the main corridor of the core store, which stays within the recommended range on average 50% of the time. As for the humidity levels, all of the areas are only within their recommended ranges for on average 38% of the monitoring period. Except for the magnetic tape area, which for 80% is within the recommended guidelines. These values are low and cause some concern, but it must be remembered that most of the material is stored within some kind of tray or box. These help to reduce the effects the surrounding environment has on the material stored within them.

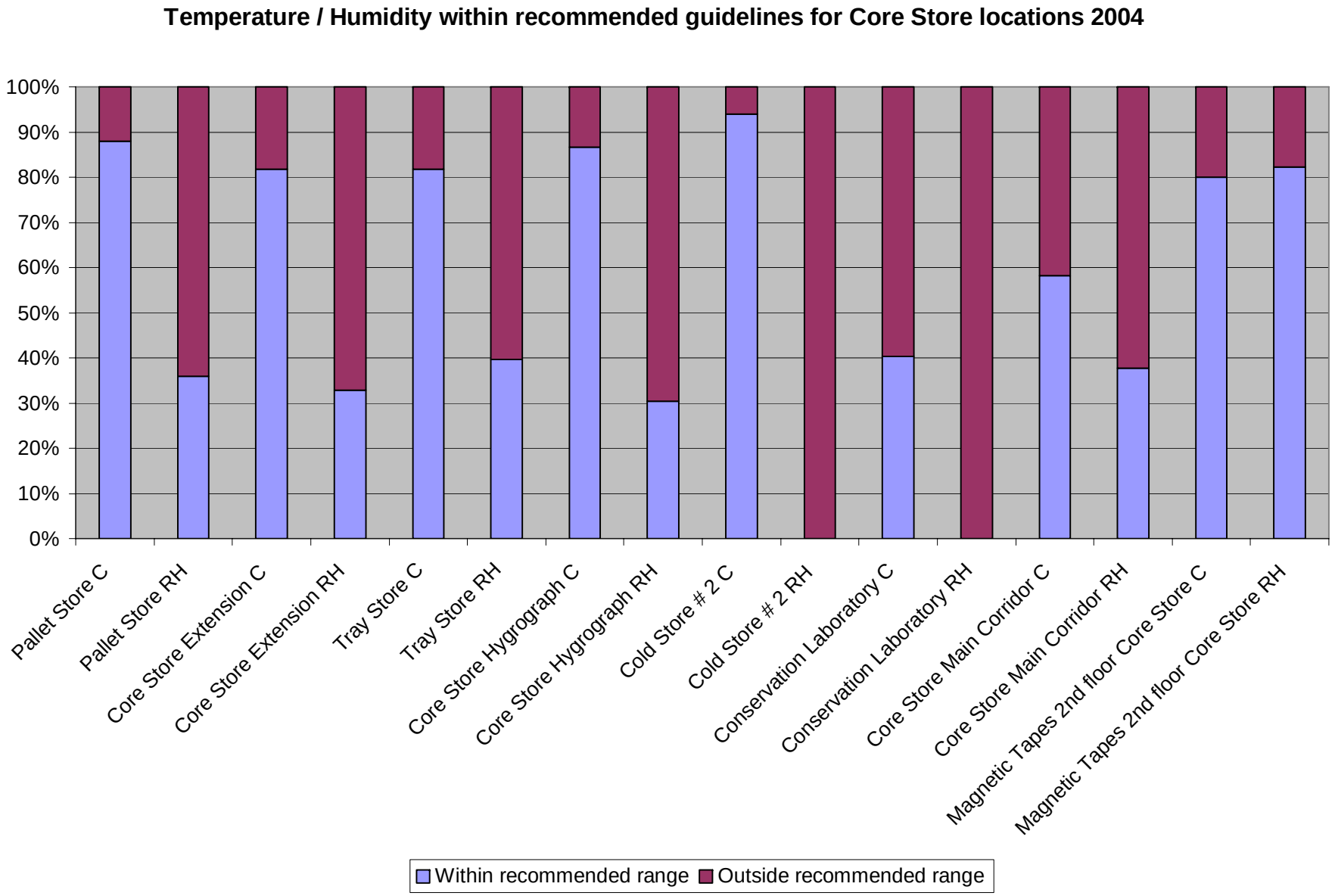

Figure 19: Temperature & humidity within guidelines for Core Store locations 2004

2.5 ADDITIONAL MONITORS WITHIN THE MUSEUM 2004

Like the core store area, additional monitors have been placed around 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 Library

As discussed in last years report *Shepherd & Tulloch, 2004*, most of the museums fossils are stored within Mahogany cabinets, or glass wall cabinets. There is a collection of large sub-fossil bone specimens that are housed on top of the wall cabinets on the ground floor of the museum. These are currently not stored in cases, but are open to the environmental conditions of the museum. It was decided to monitor this part of the museum and thus see if the specimens were being suitable stored.

Situated on the ground floor of the museum is the museum's library, which houses publications, memoirs, and reports. Most of this material is stored within lockable glass cabinets, however due to limited space, there is some reference material currently being stored within box files along the tops of these cabinets. This environment was monitored for a period in order to ascertain the suitability of these storage conditions. Additionally, there is a member of staff who works within the library, entering data onto a PC from the fossil collections into the BGS fossil database, PalaeoSaurus.

Plate 5: Museum display sub-fossil Bone

The Museum Library was monitored from 19th April to 17th May in one of the glass cabinets and then moved on top of the bookshelf between 17th May and 11th June. The ambient temperature and humidity of documents on paper should be between 13-18°C and 55-65% respectively, as suggested in *Doughty & Brunton, (1993)*. The monitor next to the sub-fossil bone was activated from 2nd August 2004, where the recommended parameters should be between 16-22°C and not below 40%RH.

2.5.1.1 Museum Sub-fossil Bone and the Museum Library Results

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

Over the four-month monitoring period of the sub-fossil bone, the results are quite surprising. Considering these large specimens are not protected by display cases and thus exposed to the environmental conditions of the museum, the temperature is often with the 16-22°C range. There

are occasions where this does drop below the 16°C mark during the winter months, but this not a regular occurrence. The results from the humidity sensor are also quite satisfying, where the majority of the time readings exceed the minimum 40%RH. However the extreme fluctuations do give cause for concern, as sub-fossil bone is susceptible to slight changes in the environment. High humidity can cause the bone to swell and can aid in the development of efflorescent growths. *Child, (1994).*

The temperature readings from the top shelf of the museum library have increased slightly by 5°C, compared to those readings taken in the glass bookcase for the period before. Still, both sets of temperature readings are above the maximum recommended temperature for this type of material. On the other hand, both library localities are significantly below the recommended minimum humidity range of 55%. There are a 'few' occasions where the humidity levels increase sufficiently to become acceptable. One of the main factors could be due to windows and doors being opened to make working conditions for staff, more comfortable in the museum library. With doors and windows open, hot humid air can penetrate into the building and allow humidity levels to rise.

Plate 6: Museum Library

It can be seen that the humidity readings outside the bookcase are closer to the 55%, compared to 40% within bookcase. Readings within the cabinet are more acceptable as these are constant, and thus provide a more stable environment.

Changes in temperature and humidity are not restricted just to the ground floor of the museum or the library as they are also present on the 1st floor of the museum.

Figures 21 and 22 summarise that the readings are within the 16-22°C for the Sub-fossil bone, as are the other locations within the museum, for 90% of the time. Within the museum, the current position on top of the wall cabinets is the most suited place for such material, where 88% of the time is spent with humidity's in excess of 40%. It must be remembered that some readings do exceed 70% RH, which can cause deterioration to sub-fossil bone.

For the Museum Library, figures 23 and 24 summarise the data through this two-month period. The temperature levels are above the recommendations for this type of material, including the time the monitor was placed within the glass bookcase. The same can be said for the humidity, where the majority of the time, inside and out of the bookcase the humidity levels are below 55%. Only a small proportion of the time, 5%, was within 55-65% as the monitor was recording from on top of the bookcase.

2.5.1.2 Museum Sub-fossil Bone and the Museum Library Summary

Due to the size of the sub-fossil bone specimens, this seems to be the most suitable place within the museum. Even though they do meet the requirements, there is a need to try and minimise the dramatic fluctuations in humidity levels.

As for the museum library, in and outside of the cabinets, the requirements have not been met during this short period, however the conditions within the glass bookcase provide more stable conditions.

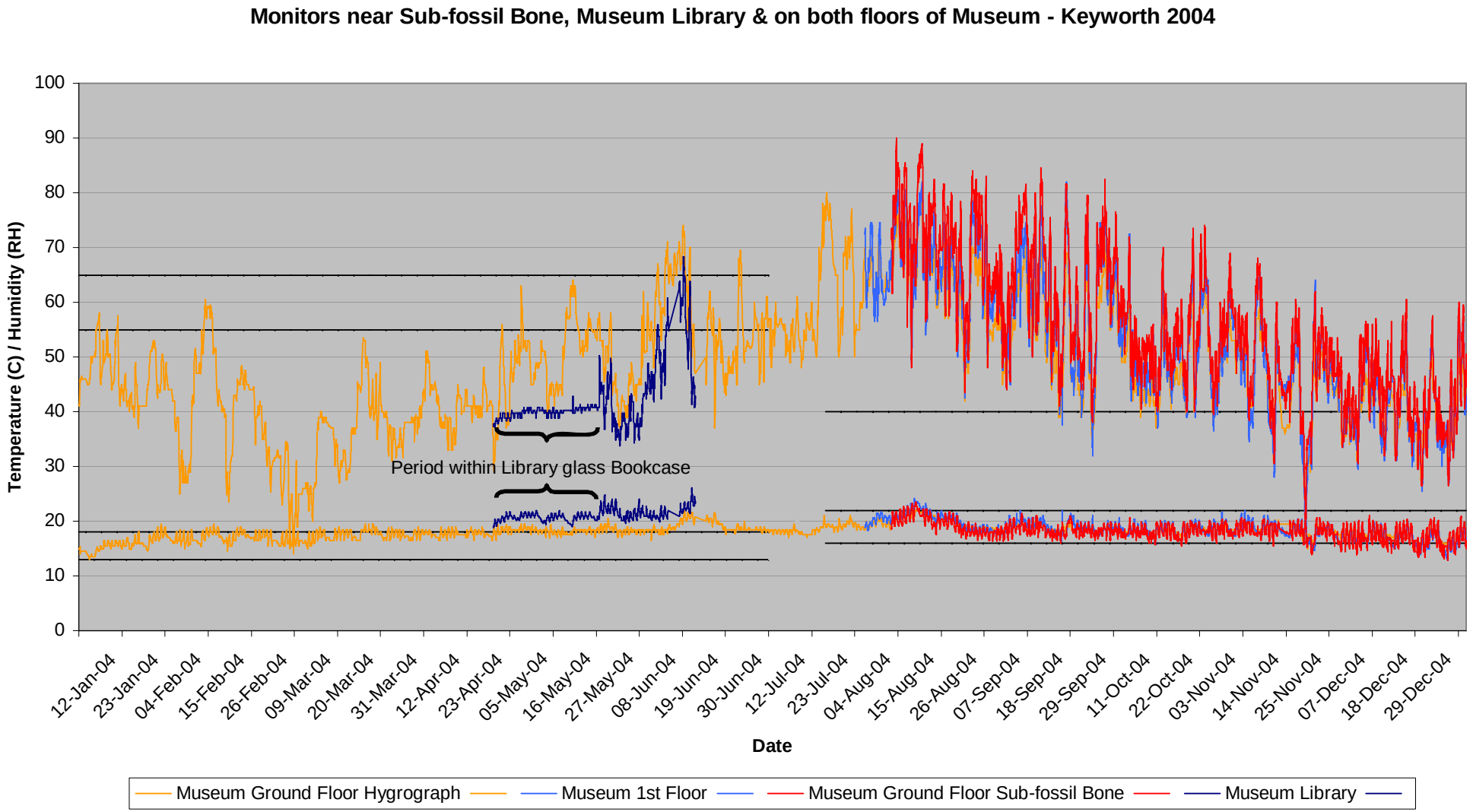

Figure 20: Temperature and humidity readings Museum Sub-fossil bone and Museum Library

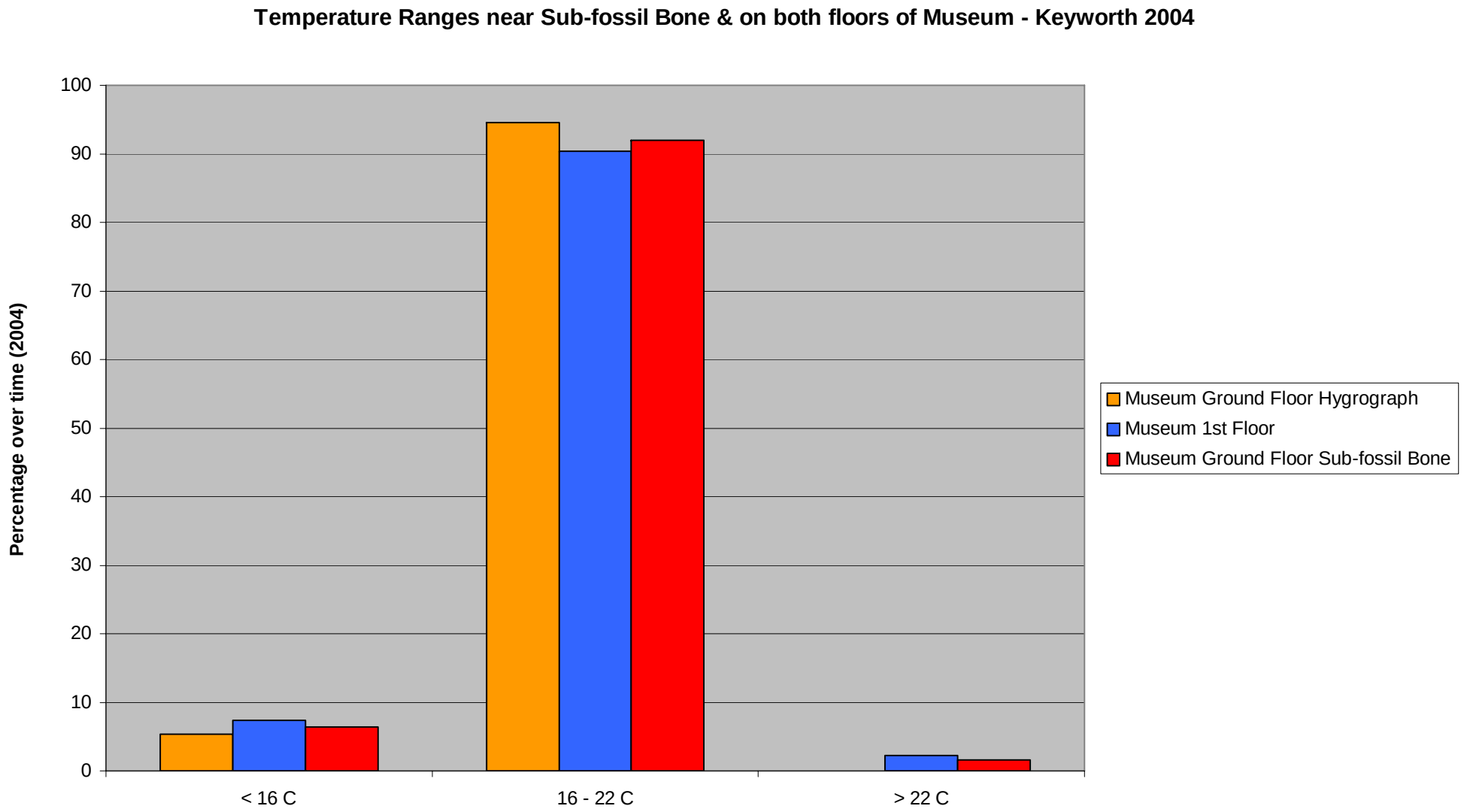

Figure 21: Histogram: Temperature ranges for Sub-fossil bone & both floors of the Museum

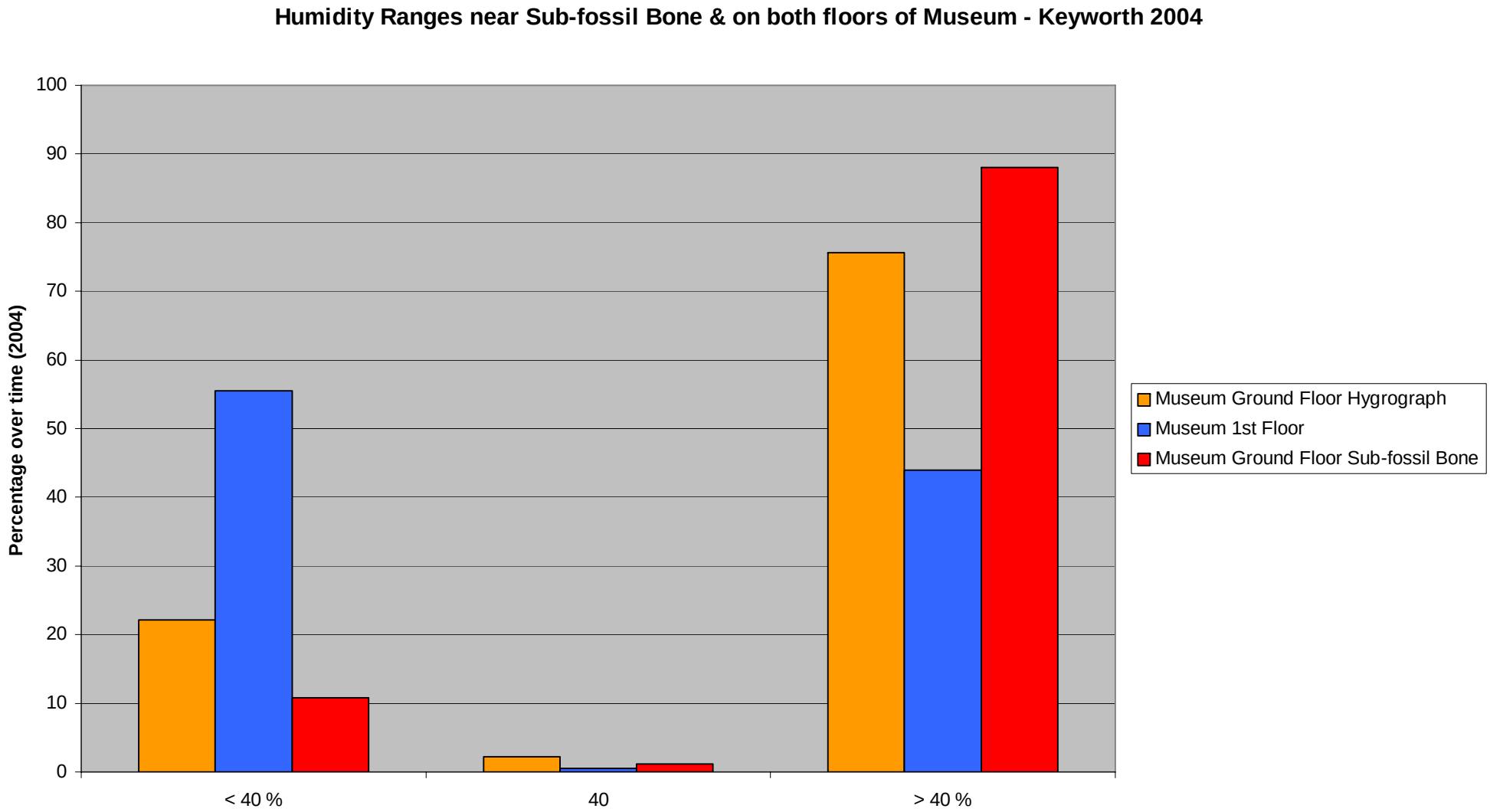

Figure 22: Histogram: Humidity ranges for Sub-fossil bone & both floors of the Museum

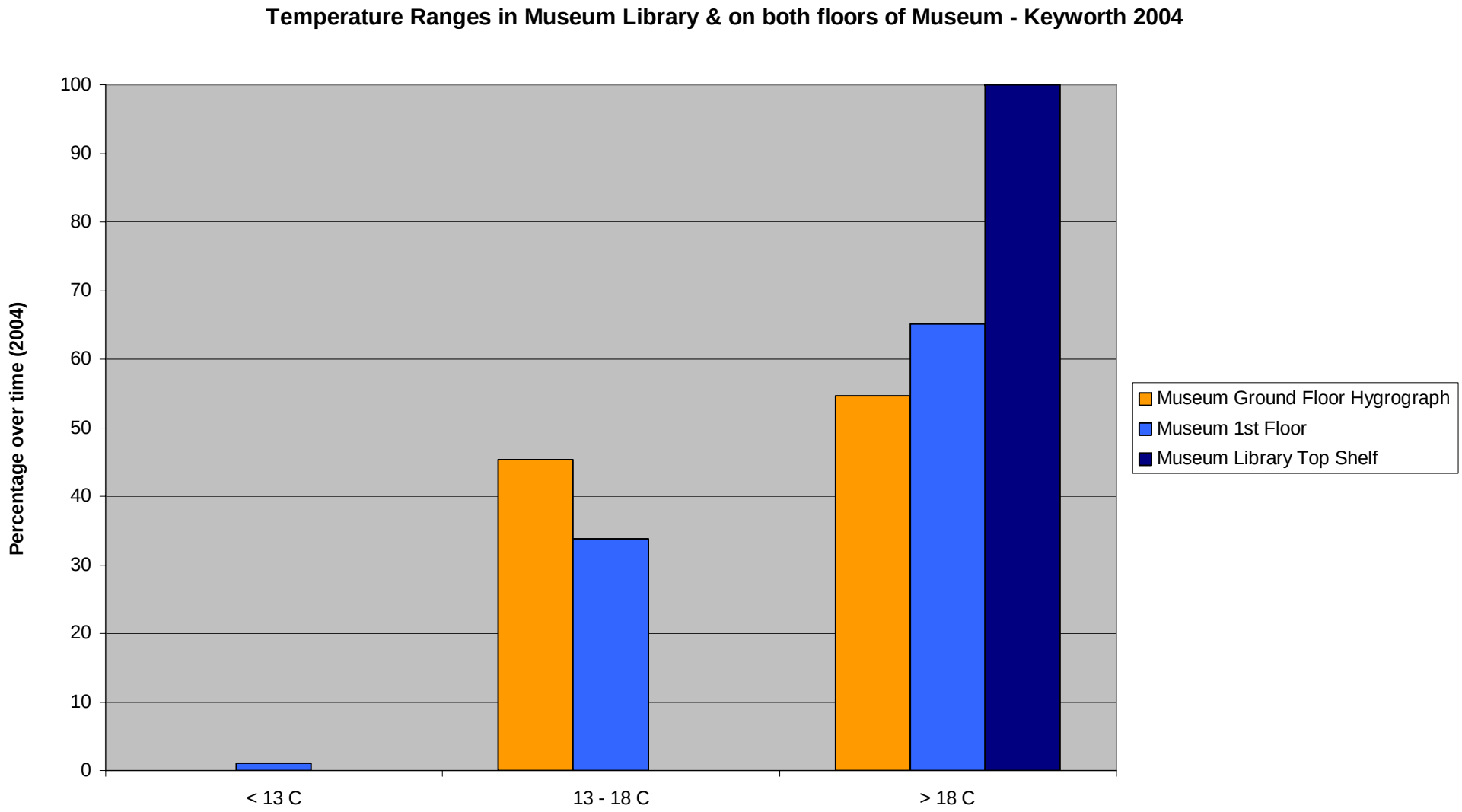

Figure 23: Histogram: Temperature ranges for Museum Library & both floors of the Library

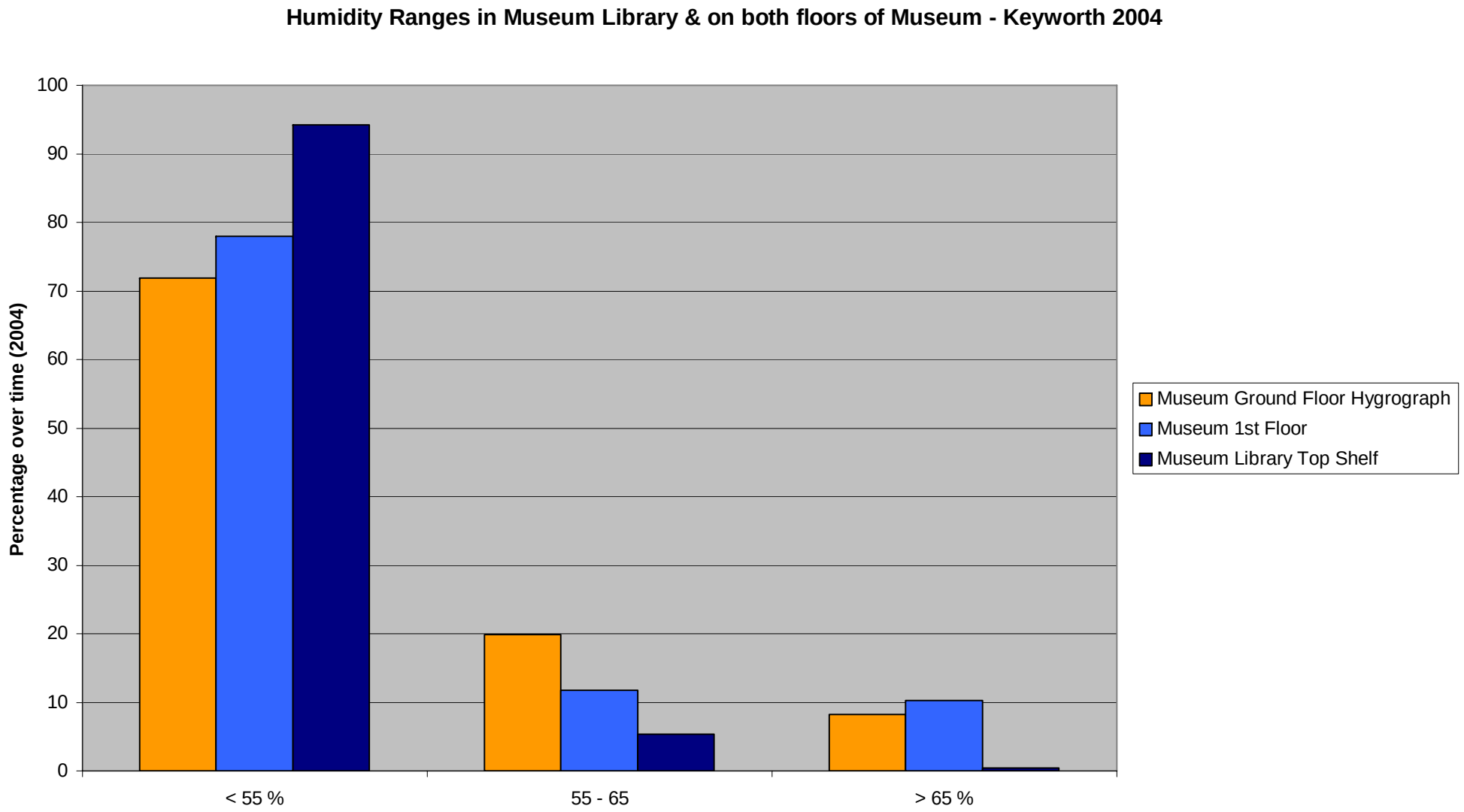

Figure 24: Histogram: Humidity ranges for Museum Library & both floors of the Museum

2.5.2 Comparisons for all Monitors within the Museum

All the data from the monitors within the museum have been tabulated onto a graph figure 25, so comparisons can be made between the different recommended parameters required for the types of material stored here.

2.5.2.1 Comparisons for all Monitors within the Museum discussion

All of the monitoring areas over their associated time intervals meet the recommended temperature requirements for 90% of the time, except the museum library, which is totally outside its recommended range. As for the humidity levels, the ground and first floor of the museum seem to be lower than required only managing 34%, whilst the museum library only spends 5% of its time within the recommended range. The only monitor to achieve higher values is next to the sub-fossil bone, where readings of 89% were maintained.

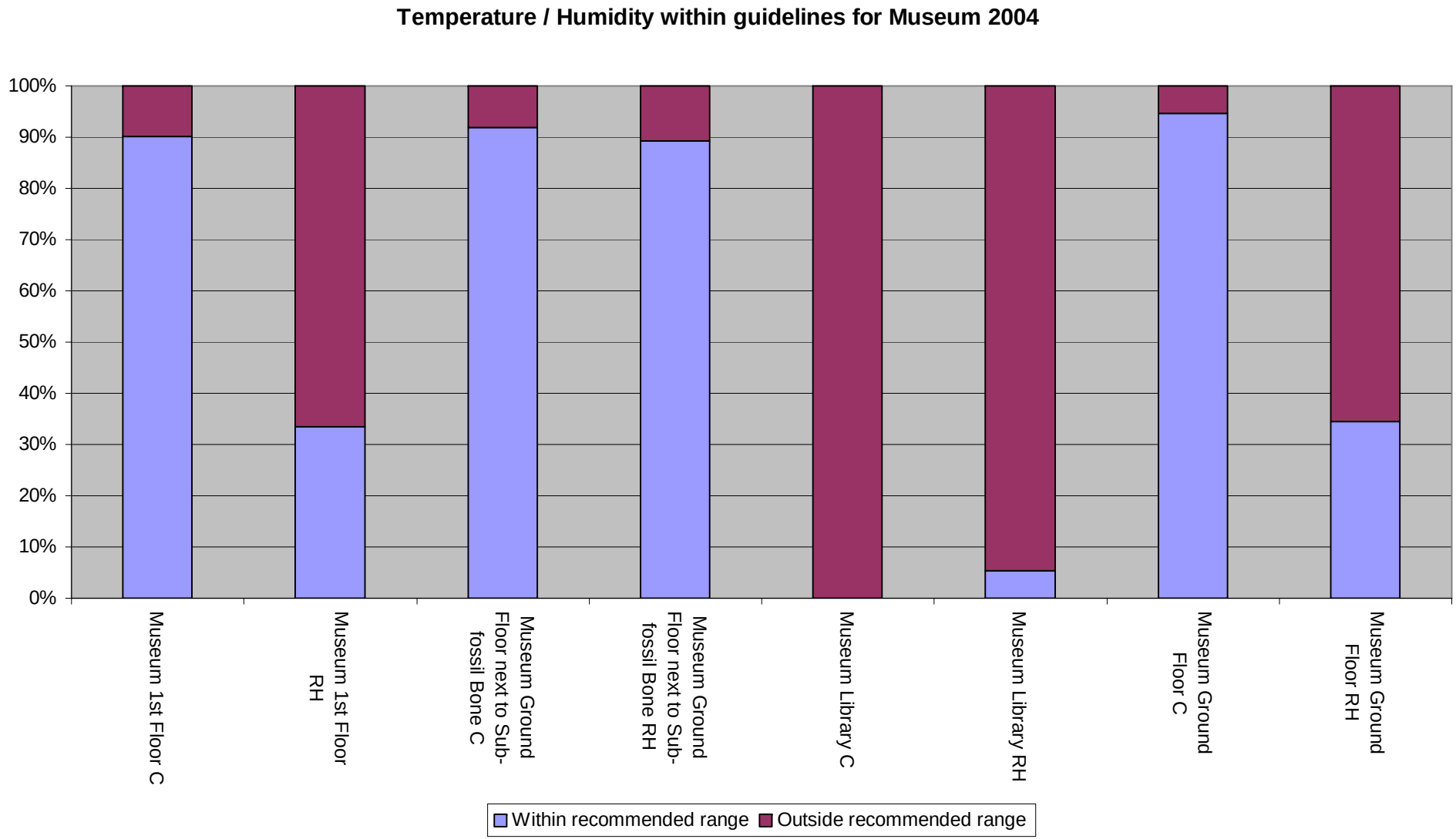

Figure 25:Temperature / Humidity within guidelines for the Museum 2004

2.6 MONITORING WITHIN THE NGRC 2004

From the 2003 report, it was recommended that the monitoring within the NGRC strong room should continue. Funding became available to purchase three additional monitors for the NGRC Records Room, rather than using a spare 'mobile' logger from previous years. This would then enable continuous monitoring throughout the year, compared to the fragmented data collected during 2003. Monitoring for the NGRC commenced after the in-house calibration period of 14th June. During this time a monitor was placed in the NGRC Strong Room in the same position as 2003 mini-project.

Plate 7: NGRC Strong Room

The other areas under investigation were within the NGRC Records Room. This houses the main part of the NGRC collection, containing reports, notebook interpretations, plans and other geological or related data. Like the strong room, this too has an automated fire suppression system. Two additional monitors were positioned at either ends of the NGRC Records Room, on shelving in rolling racking within aisles 17 and 67. After a period of four months, a decision was made to move the monitor in aisle 17, to aisle 67, into one of the cardboard boxes containing geological paper records. Any variations in temperature and humidity inside and outside of the record boxes could then be shown.

The ideal conditions in which to store historical records on paper should be between 13-18°C and 55-65 % RH, as stated in the *Standards in the Museum Care of Geological Collections 1993.* The humidity may be as low as 50% if parchment or vellum is not present, as stated in *Guidelines for the Curation of Geological Materials 1985.*

Plate 8: NGRC Records Room Aisle 17

2.6.1.1 MONITORING WITHIN THE NGRC RESULTS

The results for all areas of the NGRC are shown on figure 26, with comparisons for the NGRC Strong Room in 2003, being graphed in figure 27.

Firstly within the NGRC strong room, it can be seen that the temperature readings are elevated above the 18°C threshold by up to 7°C. There are two occasions during November 15th & 22nd when the values fall towards 18°C. This also happens in the NGRC record room. Such readings have occurred over weekends, when the heating to the site would have been turned off.

During all of 2004, temperatures were fairly constant, except for a decrease in temperature in November, as the climate cools. A similar pattern is also noticed during 2003.

The humidity values within the strong room were lower during June, July, and December compared to the rest of the monitoring period. No clear explanations can be given for this, other than that during these months; periods of lower humidity were experience. Throughout these periods, the monitors in the NGRC records room also recorded similar patterns of reduced humidity. Such periods of reduced humidity are acceptable if parchment or vellum is not present. However from August to November the humidity is around 55% the minimum requirement for the storage of documents on paper. When comparing this year results with the humidity readings for 2003, both sets of data are constant and similar. The only exception is that there is generally a 5% improvement on the humidity values for 2004.

When comparing the temperature values in the records room (aisles 17 and 67), both areas show a similar trend, where any variations are almost matched. Even though the main access to the records room is through doors near aisle 17, and that this area is used more frequently than the area around aisle 67, this shows that the airflow within the room is fairly constant.

From the 4th October, the monitor from aisle 17 was placed into a cardboard box (G239) on aisle 67. The temperature comparisons with the monitor on the shelving of the same aisle were very surprising. It is difficult to see from the graph, but the temperature fluctuations from both monitors are identical. During this period, there is a noticeable pattern that occurs on a weekly basis, with slight but elevated temperatures being recorded during the working week, whilst over the weekends readings fall by about 3°C, before they return to higher levels as work commences in the area again. Readings from both monitors in aisle 67 are showing values greater than the recommended maximum 18°C, with values more suited to general storage conditions of 16-22°C.

Plate 9: NGRC Records Room Aisle 67

When comparing the humidity readings taken from monitors in aisles 16 and 67, it can be seen that the values do not reach the minimum 55% required for the storage of paper documents. These two monitors show similar humidity readings, even though they are in separate aisles. Initially, they were both producing values around 40%, however from mid July, the humidity seems to increase. This could be brought about by, increased humidity levels recorded outside

during this period. These higher external humidity readings have then caused the internal humidity levels to stay at an elevated rate, of around 47%. Humidity readings for aisle 17 until the 4th October, always seem higher than those readings from aisle 67. This is because aisle 17 is located near the main doors into the records room, and with higher staff occupancy within this portion of the room, is enables better circulation of the air, and thus lowering the humidity levels slightly.

Comparisons for humidity values between the monitor in aisle 67 and the one in box G239, show similar readings, however neither met the minimum 55% recommended humidity. The only noticeable factor is that the humidity readings within the cardboard box are more stable, than those within the aisle itself. From this, it can be said that the cardboard box is providing some buffering effect from the humidity levels within the records room.

Figures 28 & 29, display temperature and humidity histograms for all areas within the NGRC. These figures show a different picture compared to the line graph (figure 26). Throughout this monitoring period of just over 6 months, all of the locations record values exceeding the recommended 13-18°C temperature range. The humidity levels in all of the locations fall below the recommended 55-65%RH for storage of documents on paper. However there are a few occasions within the strong room, equalling 6%, where humidity readings reach the recommended 55% minimum required.

2.6.1.2 MONITORING WITHIN THE NGRC SUMMARY

With the data collected in the NGRC strong room and the NGRC records room, it appears that all the locations follow a similar trend with temperature and humidity levels. This shows that for some time, the weather readings recorded outside, are having an effect on the internal temperature and humidity. However as the strong room is a sealed room, it is more likely that factors within the building are having a more direct effect on the conditions within the NGRC, such as insulation, central heating and airflow distribution. Both temperature and humidity readings are all outside of the recommended parameters for paper, but if parchment or vellum is not present, then for most of the time the strong room is an acceptable location to store such media. From the results gathered, it can be shown that the cardboard boxes in which most documents area are stored, do provide a buffering effect from the internal humidity levels within the records room. Such an affect is barely noticed on the associated temperature readings.

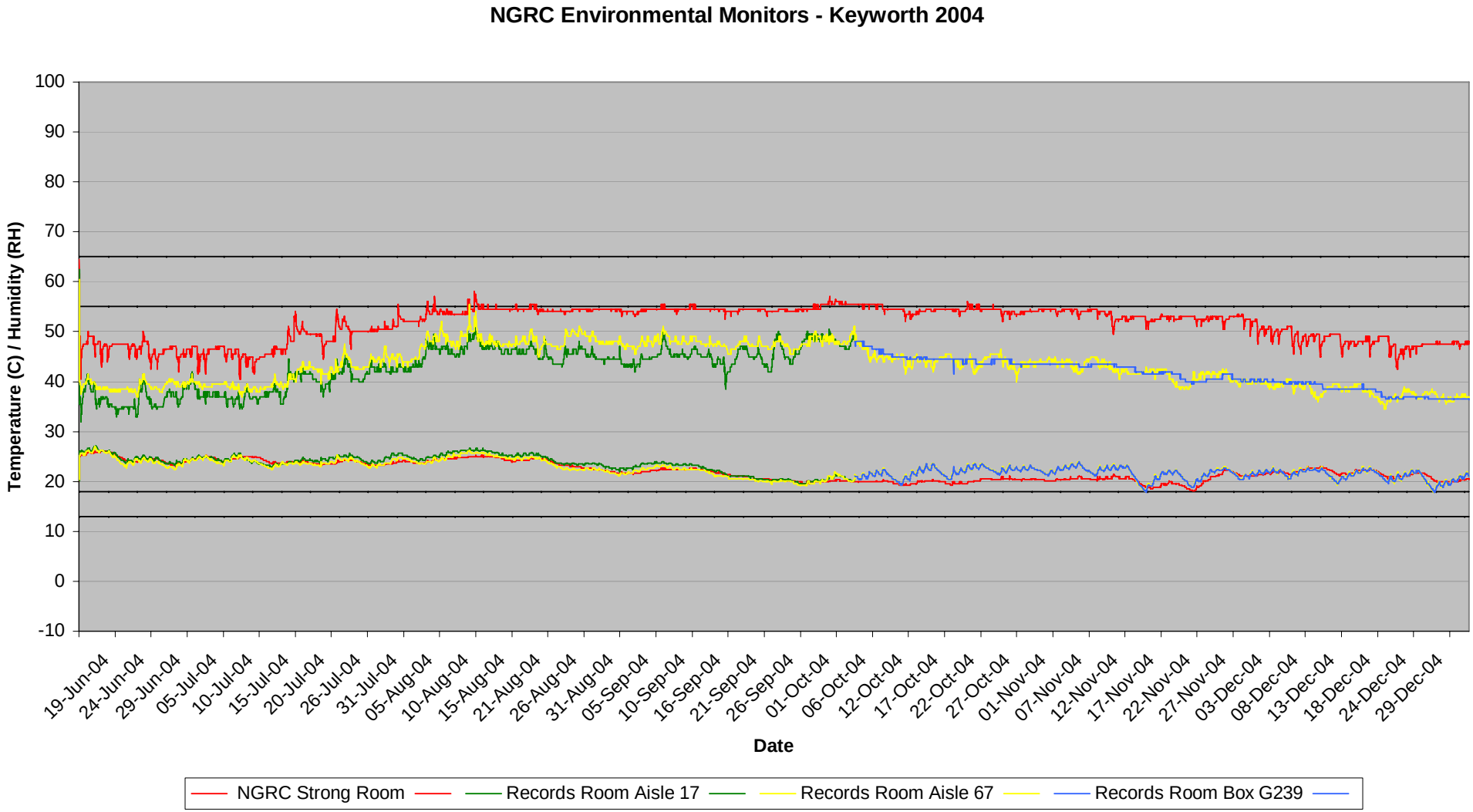

Figure 26: NGRC Environmental Monitors 2004

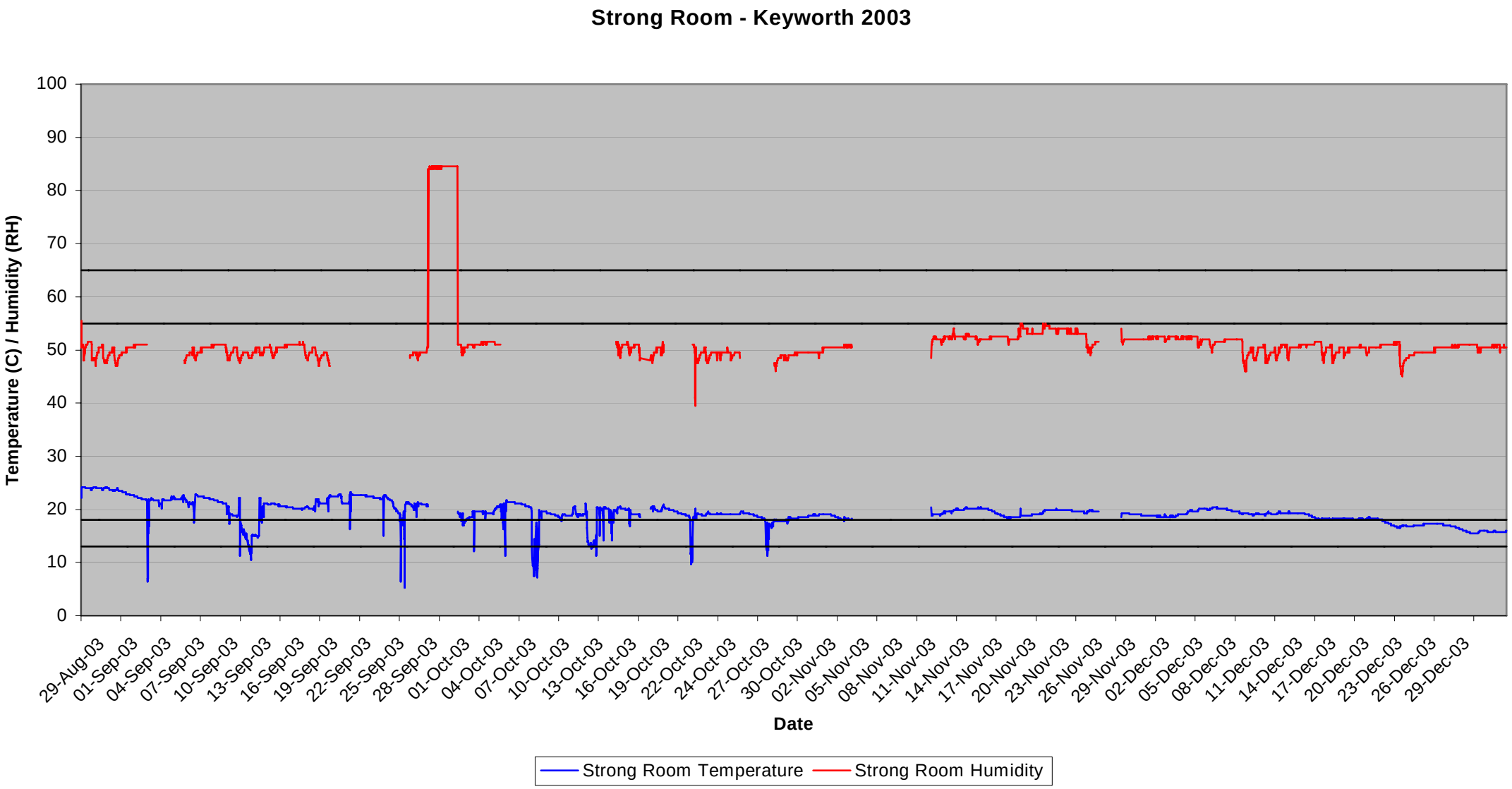

Figure 27: Temperature and humidity values within the Strong Room 2003

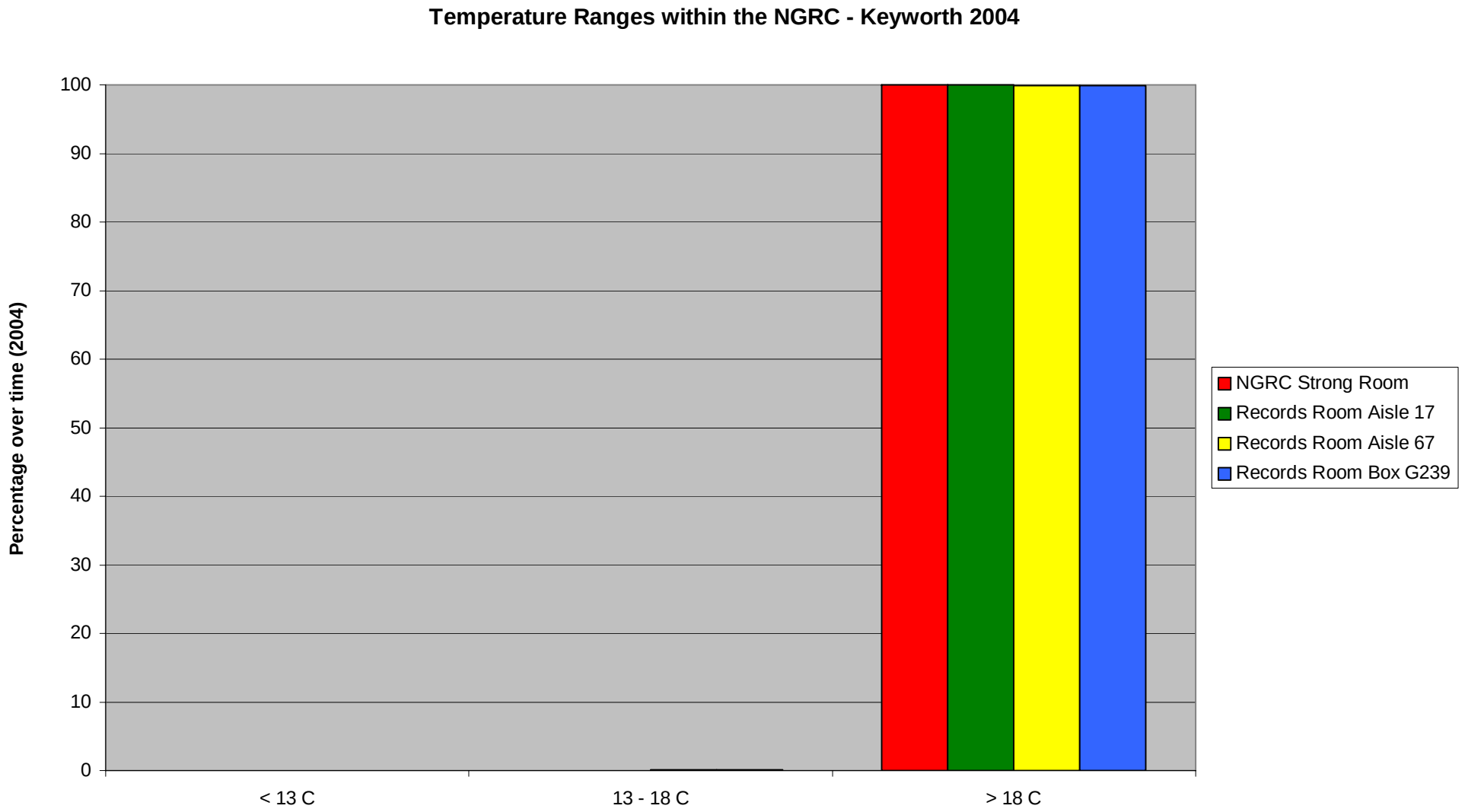

Figure 28: Histogram: Temperature ranges within the NGRC 2004

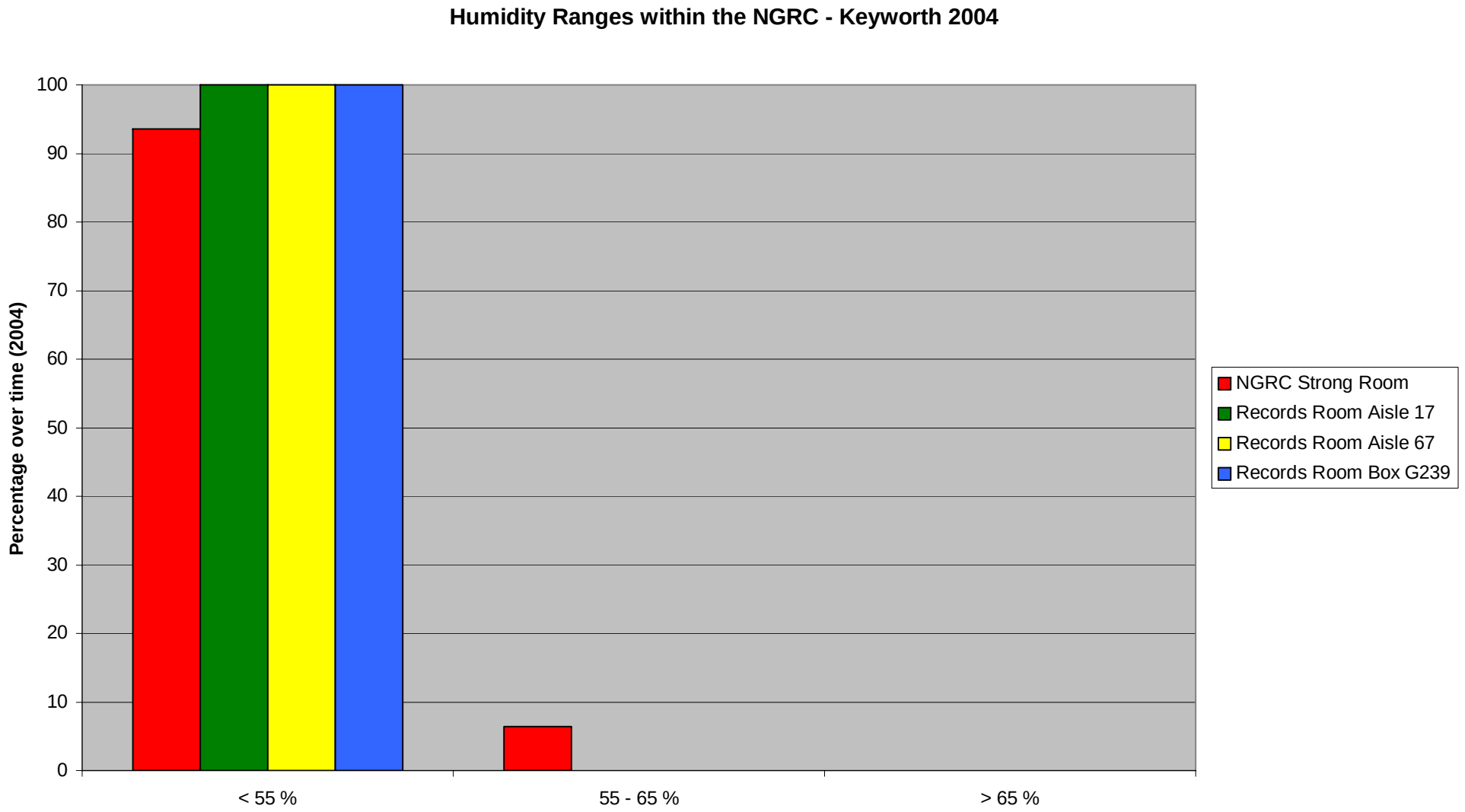

Figure 29: Histogram: Humidity ranges within the NGRC 2004

2.7 MONITORING WITHIN THE LIBRARY STRONG ROOM 2004

As the library at Keyworth has become one of the world's major earth science libraries, and due to the importance of the collections held here. It was decided to include the library strong room as part of the collections monitoring programme.

The Library Strong Room is a secure, purpose-built store on the ground floor, with a heavy-duty 'safe' door; there are no windows. Access is controlled by, and restricted to, the BGS Archivist and Library staff. An air conditioning system with ceiling vents exists, but it has not functioned for several months. Facilities Management are organising a new system and the target date for completion is 30.04.05. An FM200 fire extinguishing system was installed in this store in early 2004, replacing the former halon system.

The purpose of the store is to provide a secure and environmentally-suitable storage area for the unpublished archives of the administrative history of the Survey, and also for rare and/or valuable published items held by the Library, aiming to comply with BS 5454:2000. The Survey is a recognised Place of Deposit by the National Archives.

The Library Strong Room contains:-
1. The Archives of the administrative history of the British Geological Survey, and associated material. These comprise correspondence, letterbooks, papers, registered files, photographs, drawings etc., dating from c1800 to the present. There are also a few artefacts such as microscopes, cameras, and items presented to former staff, such as a pair of ceremonial swords presented to Sir Roderick Murchison. There are collections of material associated with former staff.

2. Items held on deposit with BGS, such as the geological photograph collection of the British Association for the Advancement of Science.

3. The Library pre-1900 Rare Book and Rare Map collection, including many valuable items e.g. a copy of the 1815 William Smith map 'A delineation of the strata of England and Wales with part of Scotland'. Archive copies of each printed BGS map held by the Library are also held in this store.

Plate 10: Library Strong Room

Monitoring commenced on the 9th November 2004, with a new monitor purchased. This was not included during the calibration period. As this monitor was recently supplied from the manufacture, and should be accurate.

The ideal conditions in which to store historical records on paper should be between 13-18°C and 55-65 % RH, as stated in the *Standards in the Museum Care of Geological Collections 1993*. The humidity may be as low as 50% if parchment or vellum is not present, as stated in *Guidelines for the Curation of Geological Materials 1985.*

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.

The temperature readings over this two-month period are just within the recommended 13-18°C range. However on one occasion this is exceeded by 1.3°C. Results during this period are fairly stable providing a reasonably suitable environment for this type of material in terms of temperature

The humidity results are showing values, which unfortunately do not meet the required 55-65% threshold, falling between 3 and 8% short. If parchment or vellum was not stored within the strong room then humidity levels are acceptable down to 50%. Based on these criteria, the strong room would then be showing readings for about 50% of the time, where humidity values would be acceptable.

Figures 31 & 32 can be used to summarise the temperature and humidity in a histogram format.

Throughout this period it can be seen that for 81% of the time monitored, the temperature readings for the strong room are within 13-18°C, where as 19% of the values are over 18°C.

The humidity values show a different picture, where for 100% of the time all of the readings are below the recommended parameters for documents on paper, 55-65%.

2.7.1.2 MONITORING WITHIN THE LIBRARY STRONG ROOM SUMMARY

Even though the monitoring only began in November, the results are worthwhile. The temperature values are within the recommended parameters, and even though the humidity levels do not reach the minimum 55% threshold, they are still constant and stable nevertheless. For historical documents on paper that do not contain parchment or vellum, then the conditions would provide a suitable environment for storing this type of material correctly. Continual monitoring throughout next year should take place, to provide more detailed readings for this storage area.

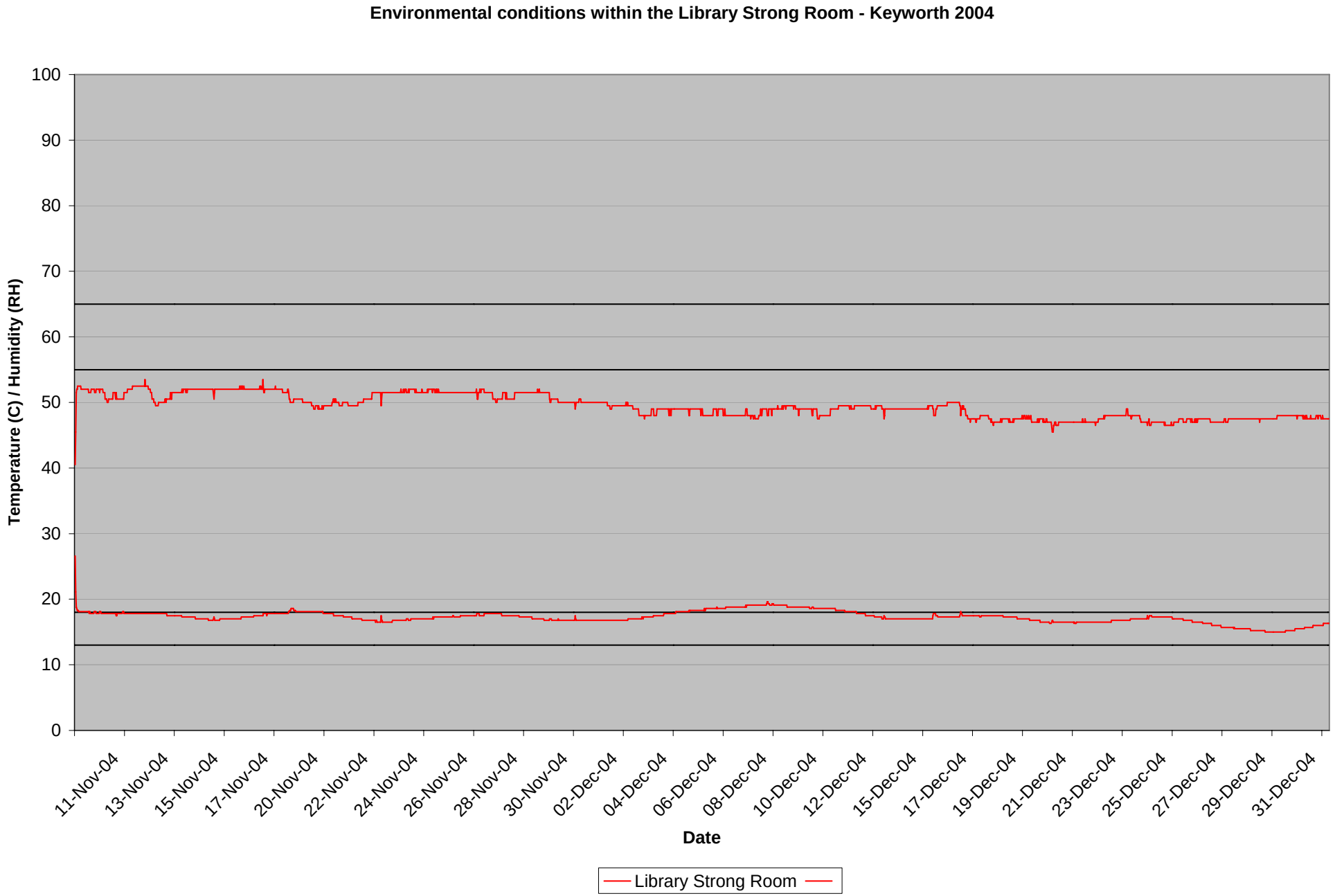

Figure 30: Temperature and humidity values within the library strong room

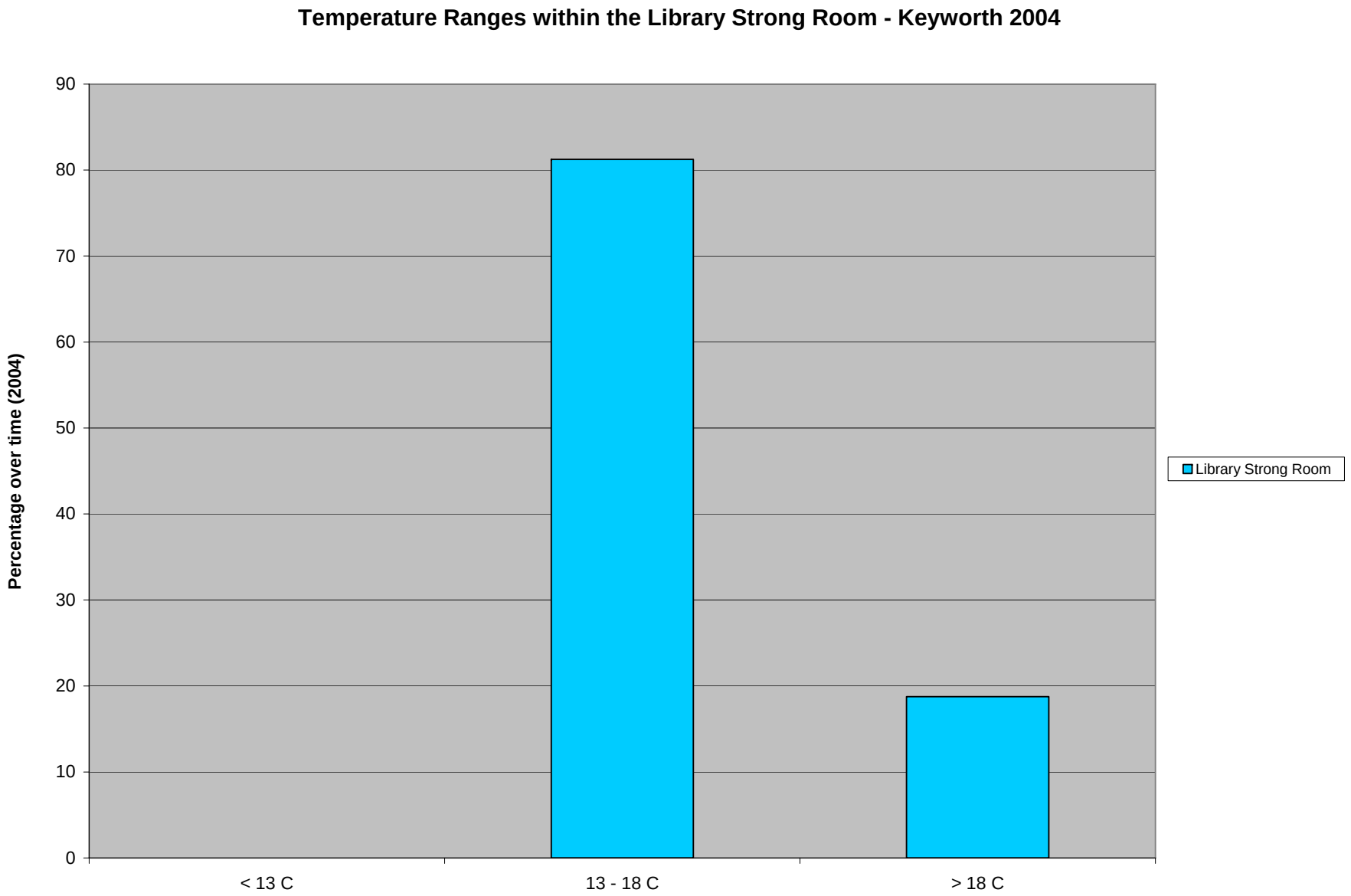

Figure 31: Histogram: Temperature ranges within the library strong room

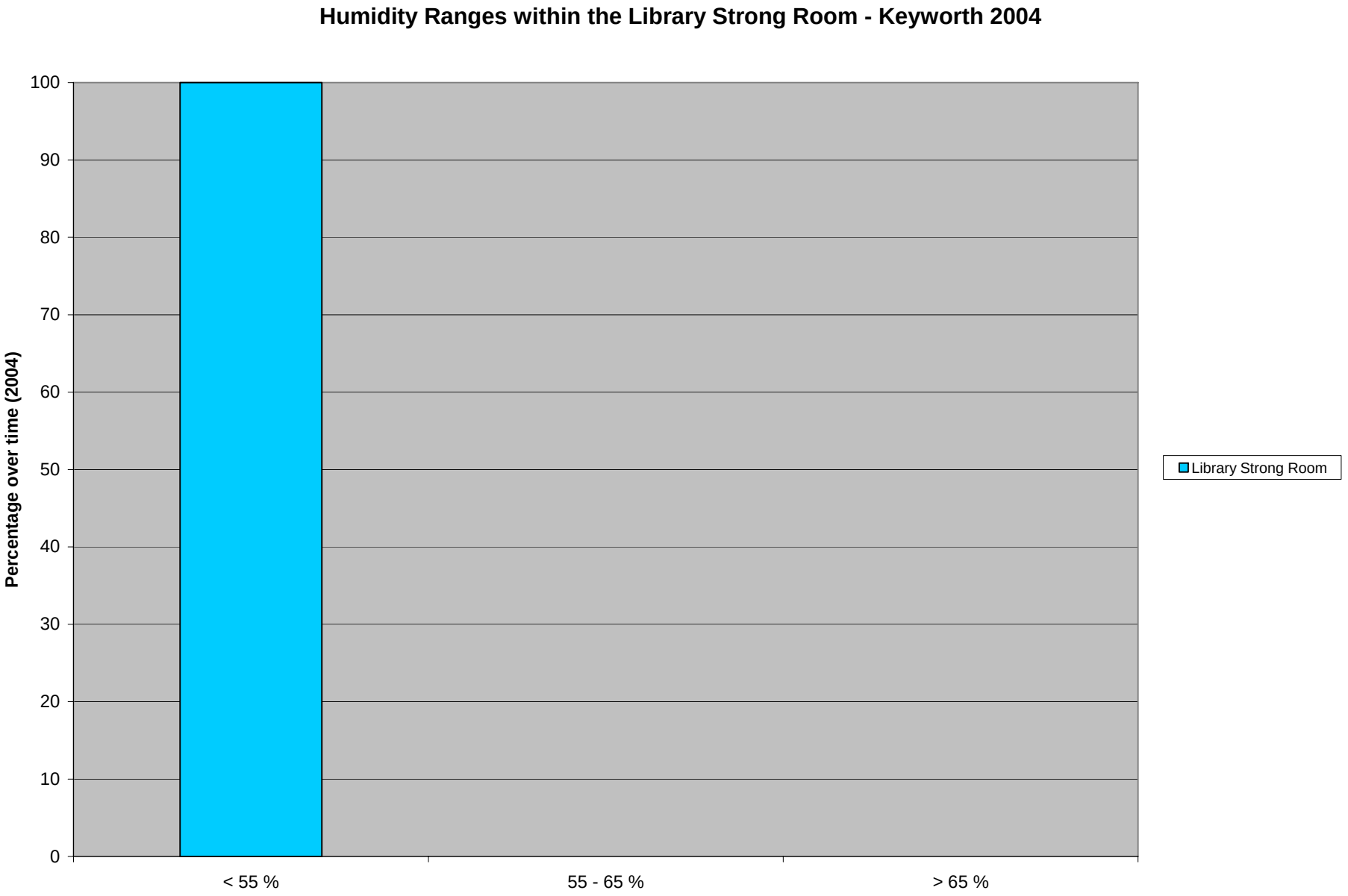

Figure 32: Histogram: Humidity ranges within the library strong room

2.8 2003 RECOMMENDATIONS ACHIVED DURING 2004 FOR KEYWORTH

Based on last years report *Shepherd & Tulloch, 2004*, the following recommendations have been achieved during 2004.

2.8.1 General monitoring

Environmental monitoring within existing key locations such as the core store and museum has continued throughout the year. The NGRC strong room and the conservation laboratory, which were previous mini projects, now form part of the continual monitoring process.

Members of staff are assisting with the identification of problematic areas. An example of this was when staff during a deep clean of the tray store discovered some trays with pyrite decay. If such a cleaning programme was not in operation then the damage to the specimens might not have been noticed for many years.

Instant visual data has been produced for this report in the form of annual histograms for all monitors within key locations, such as the core store, museum and now the NGRC.

2.8.2 Core store

From Mid November, shutter doors between the core store extension, the pallet store and the main corridor are now shut when these areas are not occupied, helping to maintain more stable conditions within these areas.

2.8.3 Museum

Museum cabinet doors are shut and locked where possible whilst not in use.

Window blinds in the museum are drawn when areas are not being occupied.

Defects within the fabric of the building have been bought to the attention of the appropriate authorities, i.e. the leaking roof on the northeast corner of the museum, which has since been repair and tested.

Sensitive materials identified by staff have been bought to the attention of the Conservator. Where full conditional surveys have been produced and microclimates created where necessary, monitoring and assessments are being carried out on a regular basis.

A number of sub-fossil bone specimens displayed above the wall cabinets in the museum are now being continually monitored during this programme. Based on additional future readings the storage of these specimens will need to be considered.

The re-organisation of some of the wall cabinets together with the possibility of additional lighting hopefully will commence in the next financial year 2005-2006.

2.8.4 Pyrite Decay & Damp Meter

Due to financial restrictions and the ability to find a suitable damp meter, this recommendation has yet to be achieved. However, additional monitors in new key areas have been included within the monitoring programme. Members of staff have identified areas of pyrite decay during the deep clean programme within the tray store.

2.8.5 Additional Monitors

An additional eight monitors have been incorporated into the environmental monitoring programme for 2004. This includes the replacement of the Casella 500+, on the first floor of the museum.

Calibrations of all monitors are carried out once a year with newly purchased monitors, which are used as benchmarks during the in-house calibration period.

The two thermohygrographs within the museum and core store, are still be used as visual aids in assessing the climatic conditions. Data from these are still extracted and incorporated within the report. Replacement of such monitors with digital monologgers, is currently not a option, as new monitors have been set-up within other new areas around the BGS site.

2.8.6 Additional projects achieved from 2003 recommendations

- The monitoring of different sections within the same storage area at the same time. This has taken place within the NGRC and the museum during 2004 and now forms part of the continual monitoring programme.
- The monitoring the storage rooms containing registers and paper records within the museum library for a trail period, and the continual monitoring of the library strong room.

2.9 RECOMMENDATIONS FOR KEYWORTH 2004

2.9.1 General Monitoring

- Monitoring within the main storage areas must continue, like previous years so we can assess the effects that temperature and humidity are having on the collections; this includes records held within the NGRC and archival material in the library strong room.
- 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 to be investigated further. New areas of investigation could include the micro palaeontological slide collection and the petrology collection.

2.9.2 Core Store Areas

- Existing areas should be continually monitored throughout the year, and additional monitors should be placed in areas where readings are outside the recommended parameters, i.e. the core store extension and the main corridor in the core store.
- Comparisons within boxes of stored material and their surrounding environment should be recorded when additional monitors are available.
- Within the conservation laboratory, measures should be taken to try and increase the humidity levels, nearer to acceptable ranges. Usage patterns of the fume cupboard by staff, should also be recorded to see if this is affecting humidity.
- When funding becomes available additional monitors could be placed on each floor of the tray store, to record any climatic variations.

2.9.3 Museum Areas

- Continual monitoring of the museum library is required when additional monitors become available. Museum staff should try and allocate additional storage space for the material stored above the bookcase, in order to reduce the effects of RH on this type of material.
- A full stock take could be carried out to ascertain if the museum library contains material on parchment or vellum. If so, a designated area could be set up to contain such types of material.
- As environmental data has been gathered for the area around the sub-fossil bone, a full conditional survey should be completed, to monitor the effects of these specimens within their current location. Buffering measures should be implemented to minimise the effects from the sudden changes in humidity, without affecting the appearance of the display.
- As a monitor is positioned on each floor of the museum, perhaps an additional monitor, when funding becomes available, could be permanently placed in a museum cabinet for comparative purposes.

2.9.4 NGRC Areas

- Continual monitoring is required for all existing areas, especially the monitoring of temperature and humidity within the storage boxes compared to within the aisles.
- A full stock take could be carried out to ascertain if these areas contain material on parchment or vellum. If so, a designated area could be set up to contain such types of material.

2.9.5 Library Strong Room

- Continual monitoring of this area is required.
- As the strong room is large in size, additional monitors should be purchased. Any variations in temperature and humidity could be recorded within a different area of the strong room. Alternatively monitoring could be adjacent to material that is more susceptible to environmental change or requires specialised conditions for storage.
- A full audit could be carried out to ascertain if the strong room contains material on either parchment or vellum. If so, a designated area could be set up to contain such types of material.

2.9.6 Miscellaneous Areas

- An additional monitor should be located in the Stevenson Screen to continually monitor the external temperature and humidity. This recommendation was not achieved during 2004, and should be carried forward to 2005. This would provide us with more readings throughout the day and record values over weekends. Such data would help us to compare internal and external readings more accurately.
- A record of weather conditions and precipitation levels could be collated and used to determine any effects on temperature and humidity levels, both externally and more importantly within the collections.

3 Monitoring at Murchison House

Eight Digitron loggers are used to gather internal temperature and humidity data in Murchison House, three in the Palaeontological storeroom and four, including a mobile unit, in the Petrological store, in addition to these there is a second 'mobile' unit currently located in a cabinet the main entrance of the office, see Figure 33. An additional system, located on the southeast roof of Murchison House, is used to capture weather statistics.

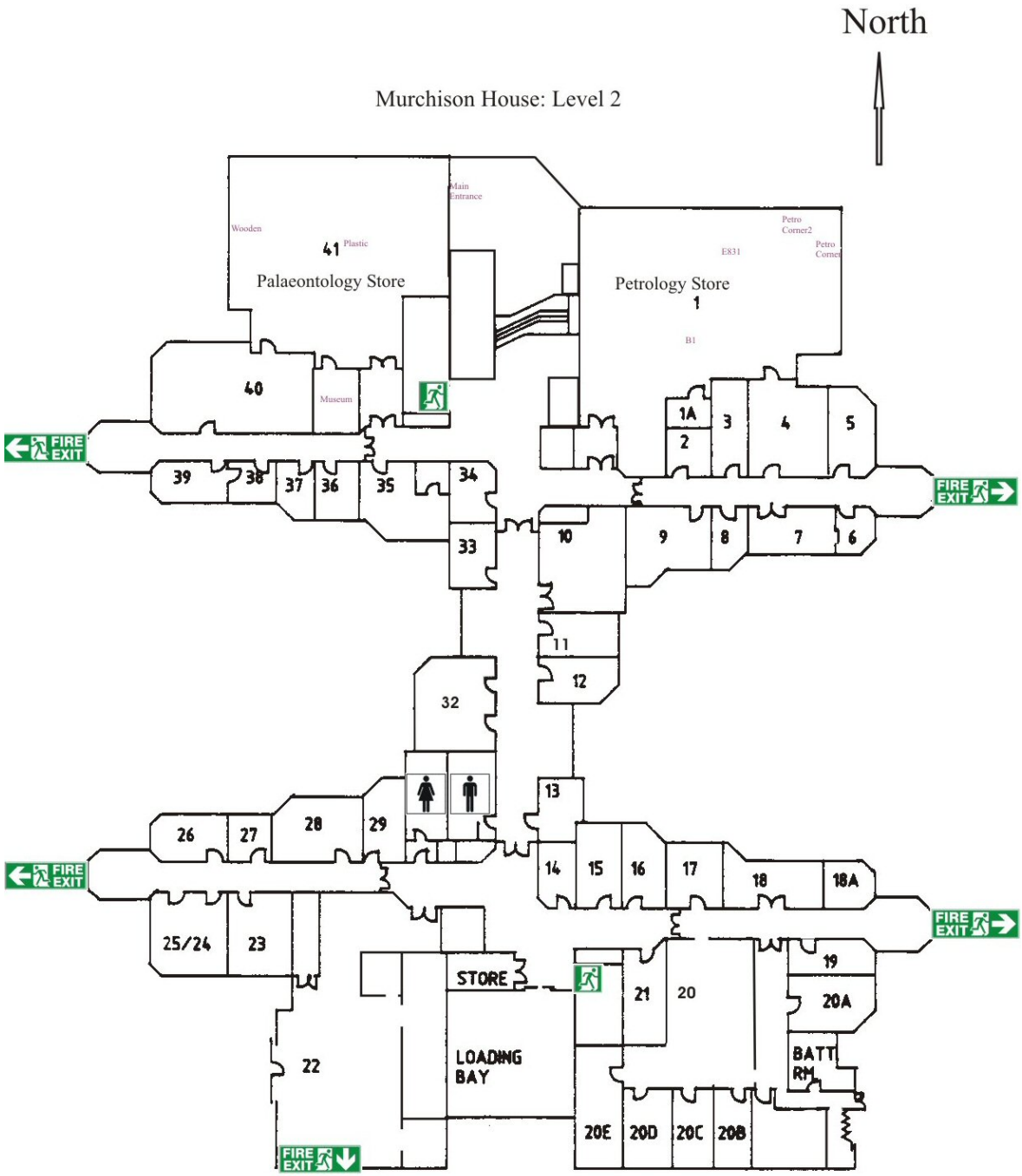

Figure 33: Location of Murchison House loggers

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. A third is monitoring an area of particular concern and is also in the open. The 'mobile' unit was also placed in this corner to determine if there was a difference between the two adjacent walls.

The logger housed in the entrance display cabinet was installed to determine the suitability of the cabinet for specimen display.

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

Data from the Weather Station are stored automatically on a computer in daily ASCII files and downloaded with the extensions .MHU and .MTA (Murchison House Humidity & Murchison House Temperature).

The Excel spreadsheets labelled "2003 Data.xls" and "2004 Data.xls" contain data for 2003 and 2004 extracted from the MSAccess database. It is from these files that the annual graphs and 'mini-project' files are produced.

The Excel spreadsheet labelled "Met data 2004.xls" contains all available Weather Station data for 2004 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 2004 the loggers were calibrated in this way twice, once each in January and June.

3.1.1 Calibration Method

The loggers were placed in an empty plastic specimen tray for two 24 hour periods between 12 noon, 14th and 12 noon, 15th January and again 12 noon 17th June until 12 noon, 18th June 2004. The calibration is undertaken mid-way 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 were returned to their usual locations and the data downloaded and graphed at the normal time on 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 graph shows that even these small changes make the data more accurate.

	January		June	
Logger	**Temperature**	**Humidity**	**Temperature**	**Humidity**
Museum	+0.2	+2.0	Same	+2.0
Wooden	Same	+1.5	Same	+2.5
Plastic	Same	Same	Same	Same
E831	+0.2	-2.0	+0.2	-2.0
B1	Same	+1.5	Same	+2.0
NE Corner	+0.2	-3.0	Same	-3.5
SE Corner*			Same	+2.0
Entrance*	+0.2	-3.0	Same	-2
Corridor*			Same	+2.0

Table 3: 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 34 and 36 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 was 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 34 and 36, the uncalibrated data is provided as a transparency; note the gaps between the lines at the time when they were in the same location. Figures 35 and 37 is the same data which has had the calibration factors applied

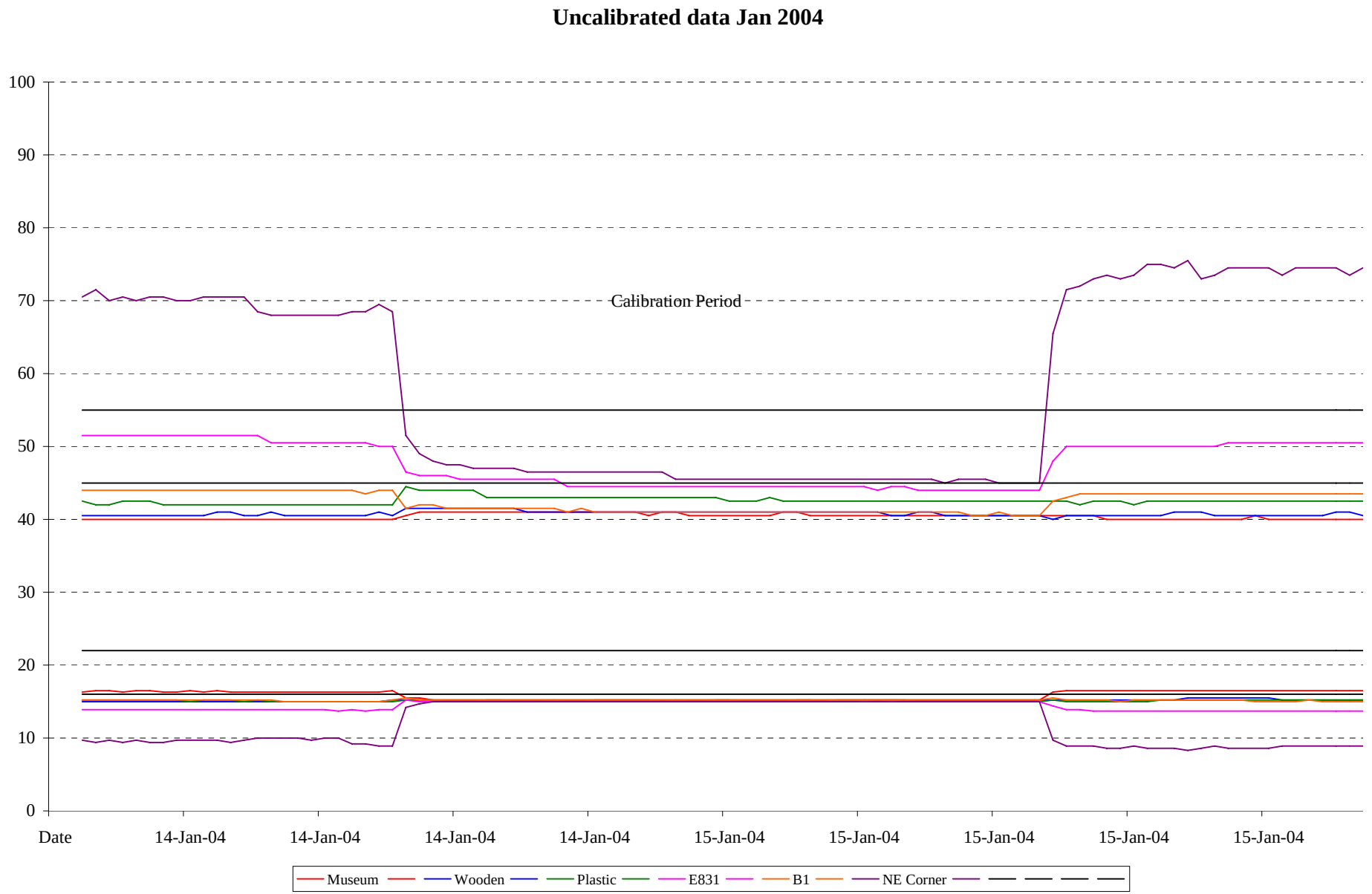

Figure 34: Uncalibrated data – January 2004 test period, Murchison House

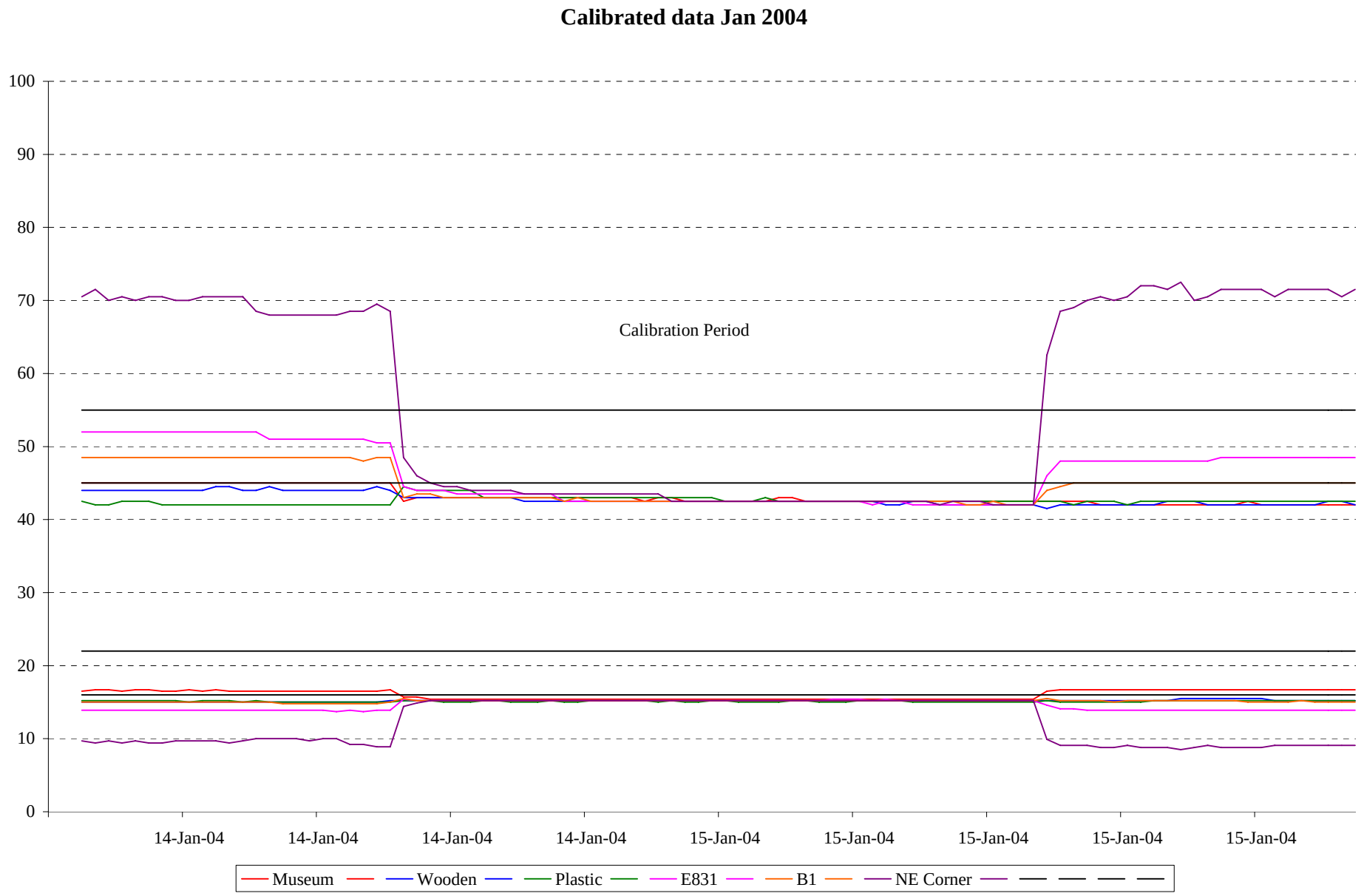

Figure 35: Calibrated data – January 2004 test period, Murchison House

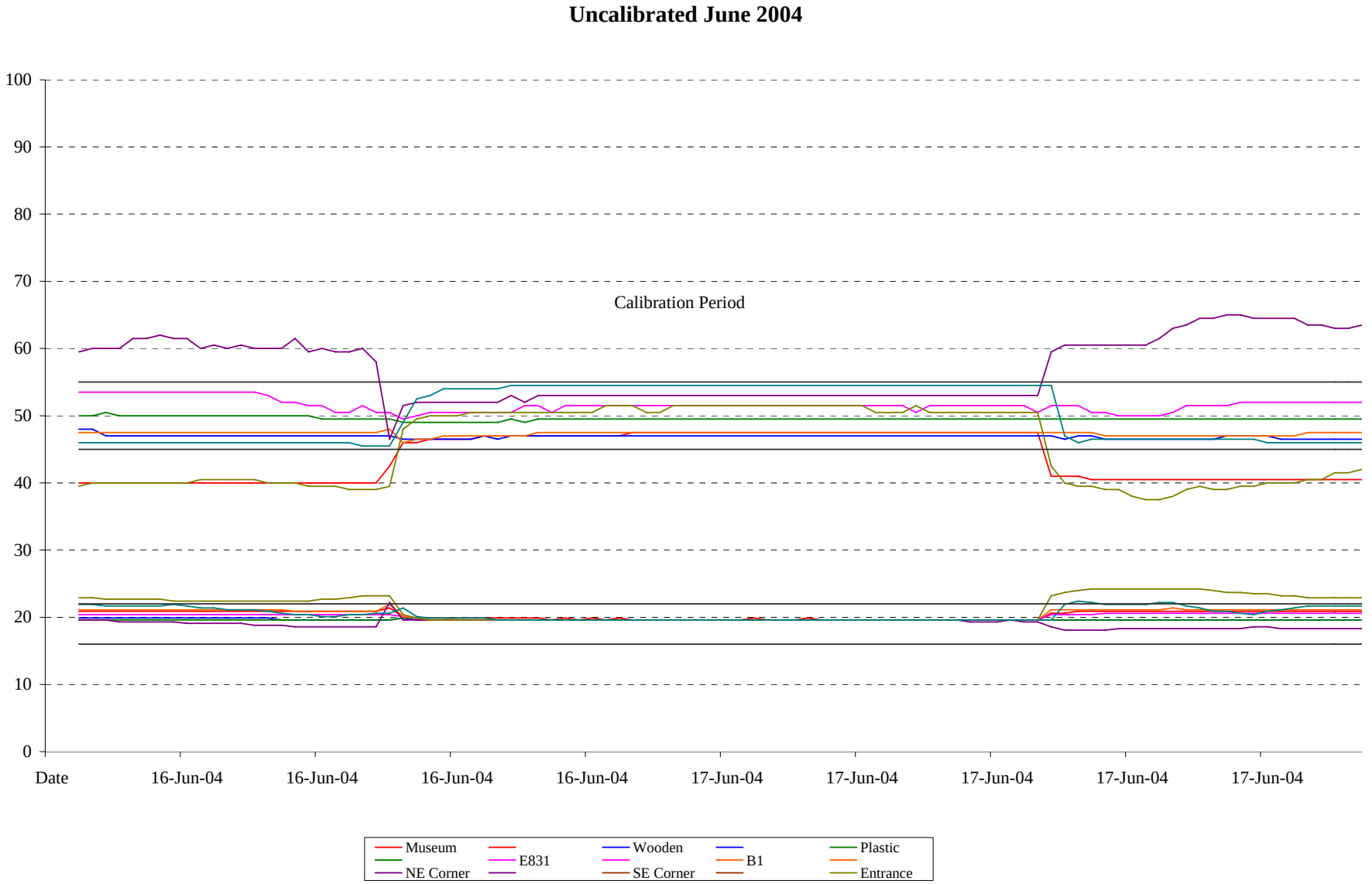

Figure 36: Uncalibrated data – June 2004 test period, Murchison House

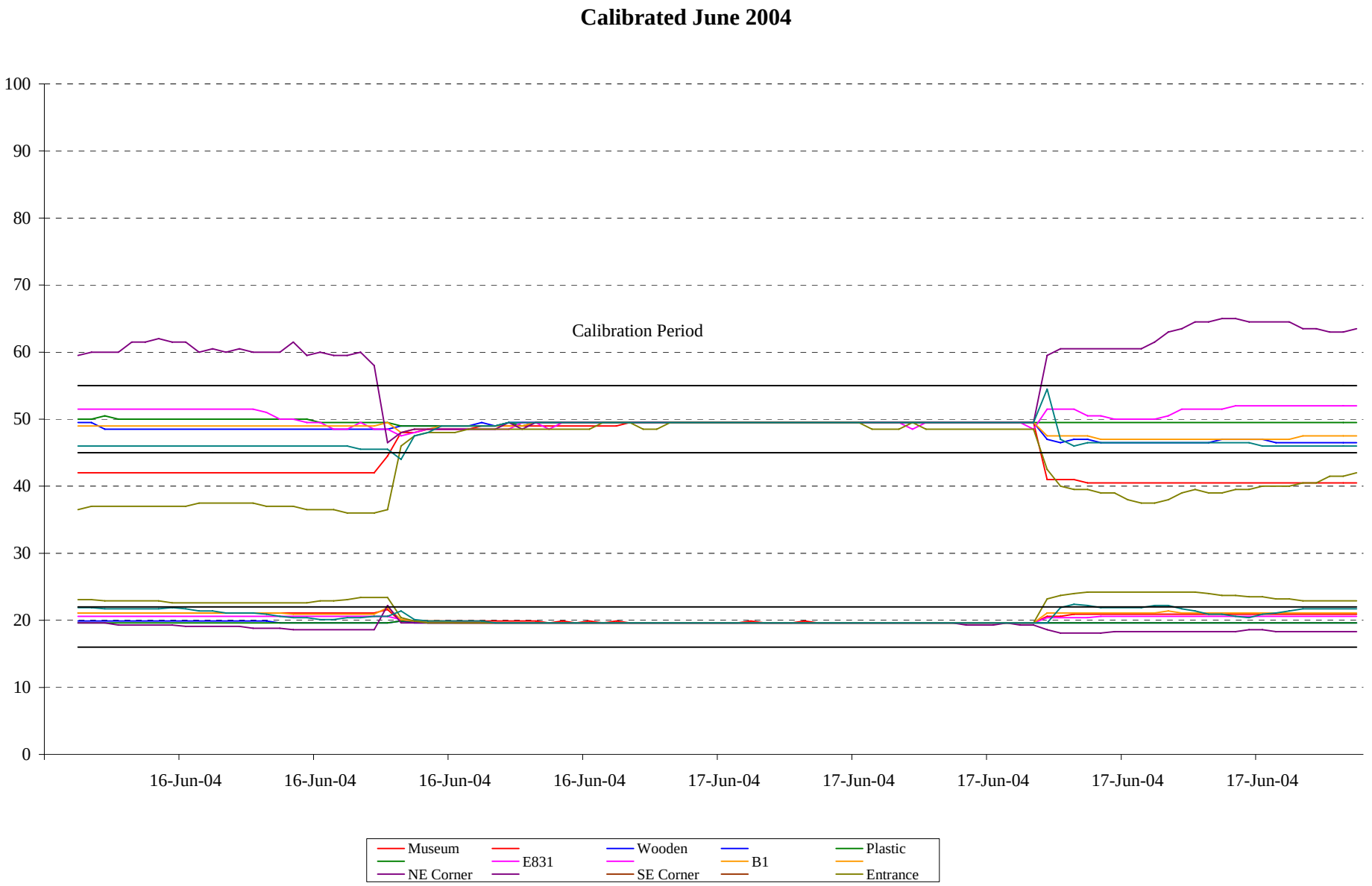

Figure 37: Calibrated data – June 2004 test period, Murchison House

3.2 ANNUAL DATA 2004

Eight Digitron loggers are used to gather temperature and humidity data in Murchison House, three permanent in each of the Palaeontological & Petrology stores and two 'mobile' units: one presently housed in a display cabinet in the foyer and another currently positioned in the Petrology storeroom.

Two loggers in the Palaeontological area are in trays in the general store and the other in a Museum specimen's 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. A third is situated on the floor in a corner of the store to monitor the humidity levels in what was previously described as a 'problem corner'; a mobile unit was placed nearby towards the end of the year.

This unit has also been used to determine the environment in a corridor display cabinet to establish whether or not the environment was suitable for particular specimens.

As discussed in previous chapters the data presented in this chapter has been calibrated to take variations in the accuracy of individual loggers into account. The time has also been altered to Greenwich Mean Time (GMT).

This chapter will confine discussion to general trends and comparisons with 2003.

3.2.1 Annual Data Discussion

Figure 39 appears to show an improvement in the general conditions in both storerooms in the calendar year 2004 compared to the previous 12 months; Figure 38.

Comparing the two graphs we can observe similar seasonal variations for 2004 as 2003, although slightly offset. The temperature readings in particular are very similar and, whilst the humidity is not as close, these readings too, are similar.

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 likewise follows this trend, although the trend here is not so apparent as it remains high and relatively flat.

The line displaying very high humidity on the 2004 graph is that from the logger not in a specimen tray: i.e. the NE corner of the Petrology store. This was not put in place until 29th July 2003 and so is absent for most of the 2003 graph, however for the data available for comparison with 2004 it shows the least similar trend to the previous year with a higher level than 2003 during August and September, although 2004 is a lower than 2003 from September to December.

Unfortunately, as will be discussed in a later chapter, it is difficult to ascertain precisely why this should be.

The amount of data from the loggers shown on one graph is confusing: to assist the reader I have divided the data into two groups; an 'Extreme Areas' group, consisting of the loggers that are not in enclosed systems or are in the foyer and a 'Main Areas' group, these are the loggers that are housed in specimen trays or display cabinets. These graphs are presented as Figures 40 and 41. The data within the temperature and humidity target boundary have been greyed out on both graphs to allow the out-of-limit data to be seen more clearly.

All data are presented by range values and a 2003/04 comparison in bar-chart format in Figures 43 to 48. From these charts is will be seen that the results for 2004 are less encouraging than initially thought from examining the line graphs.

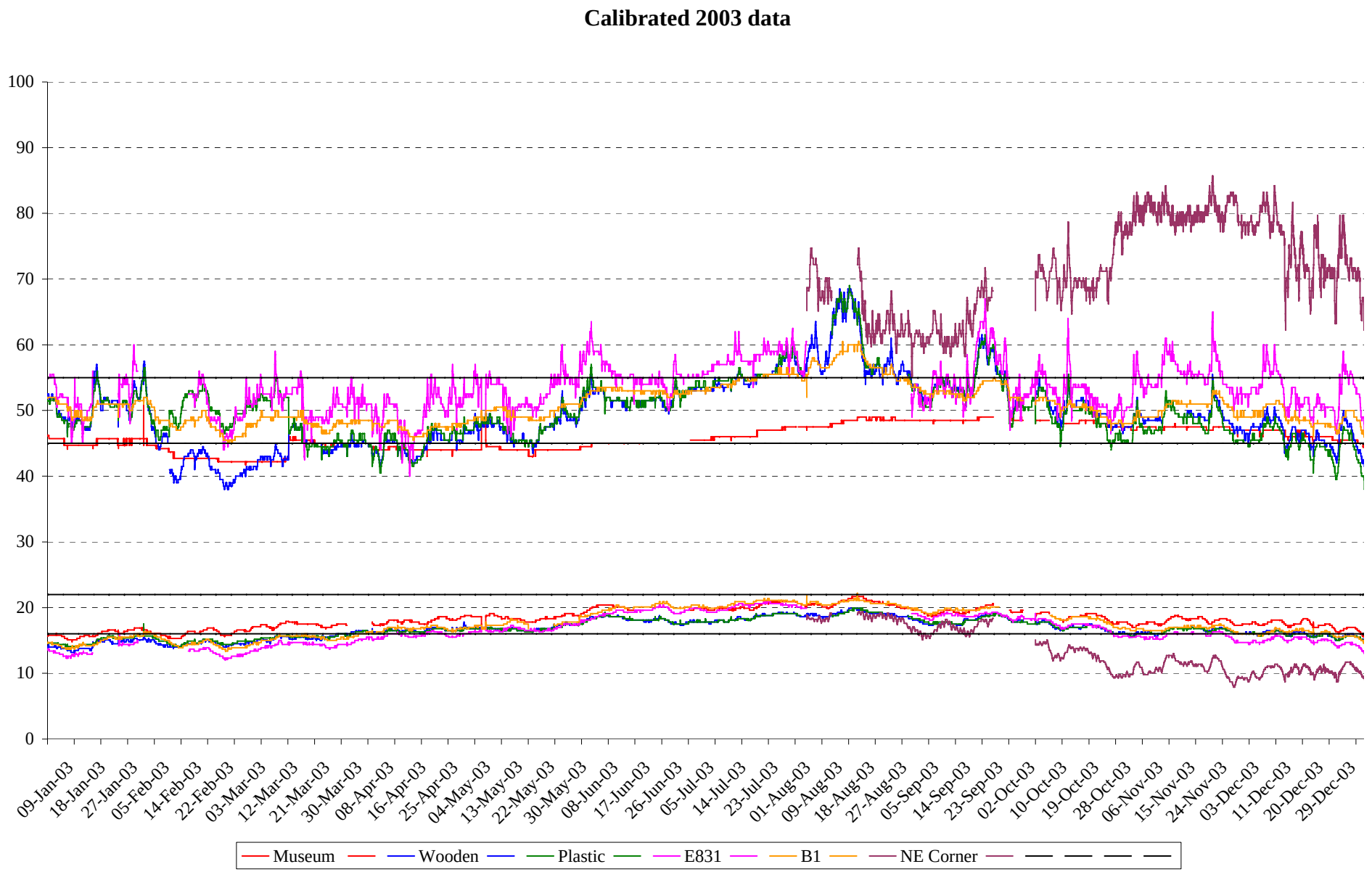

Figure 38: Calibrated data 2003, Murchison House

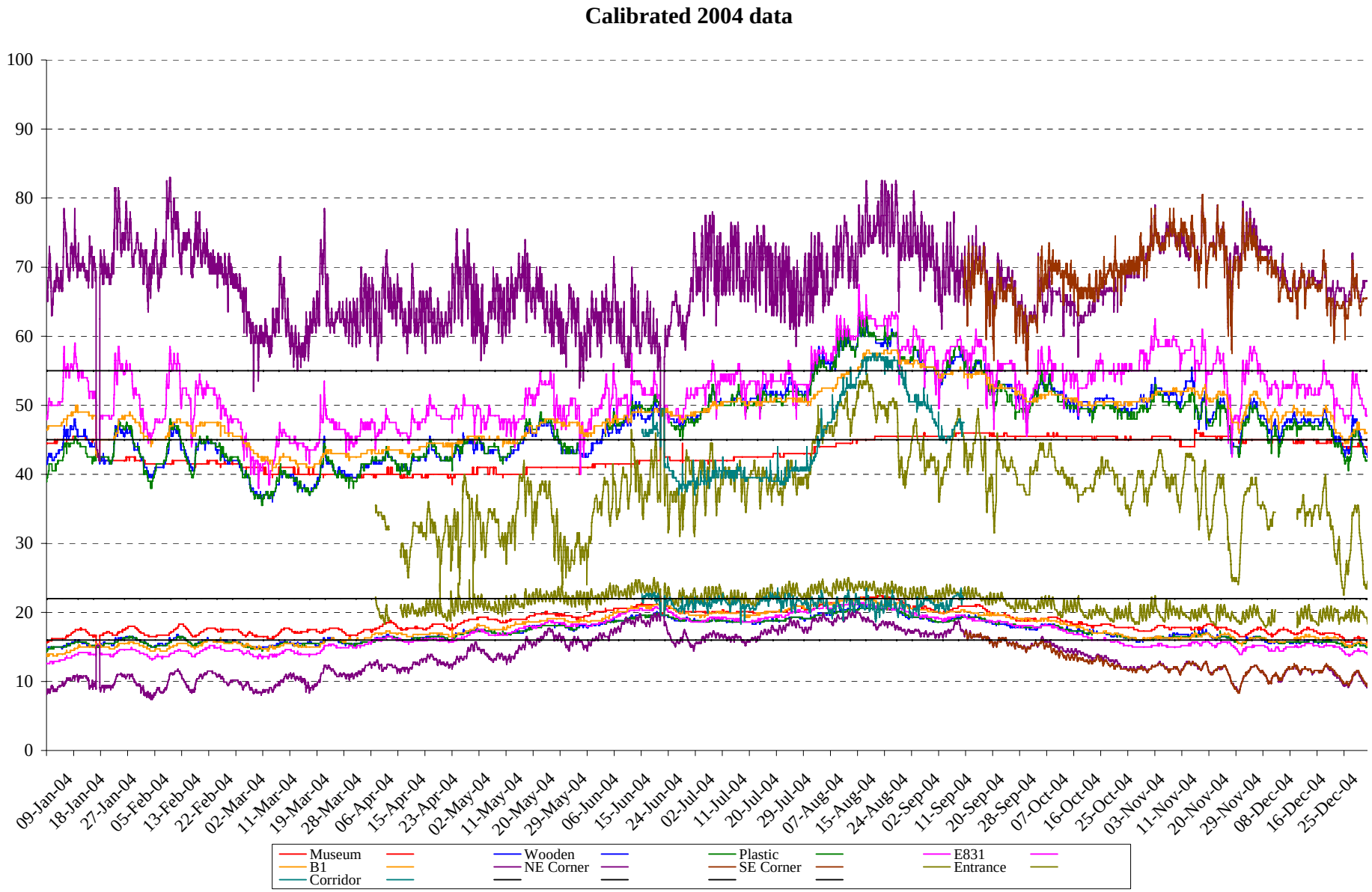

Figure 39: Calibrated data 2004, Murchison House

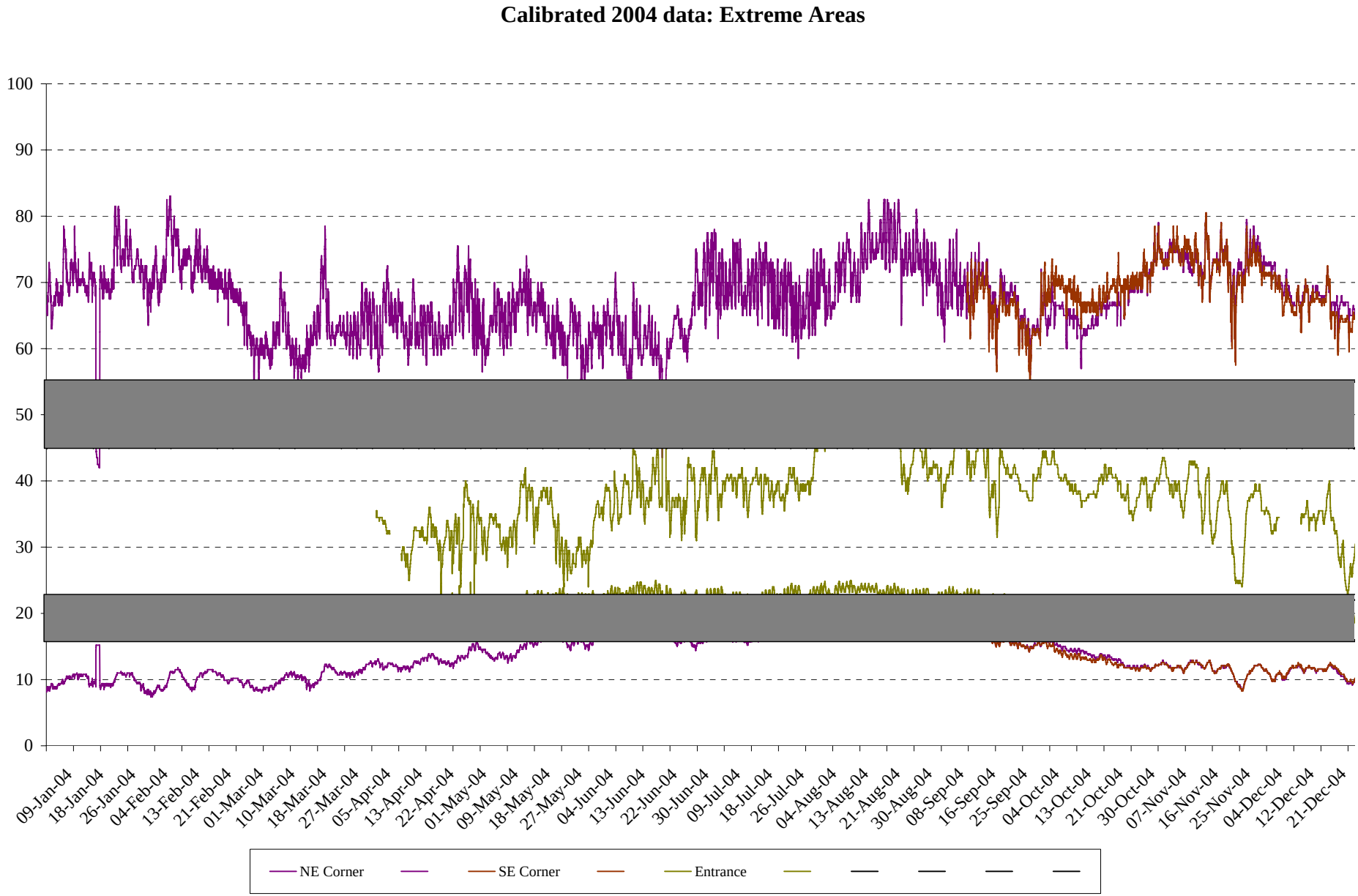

Figure 40 Calibrated data:'Extreme Areas' 2004, Murchison House

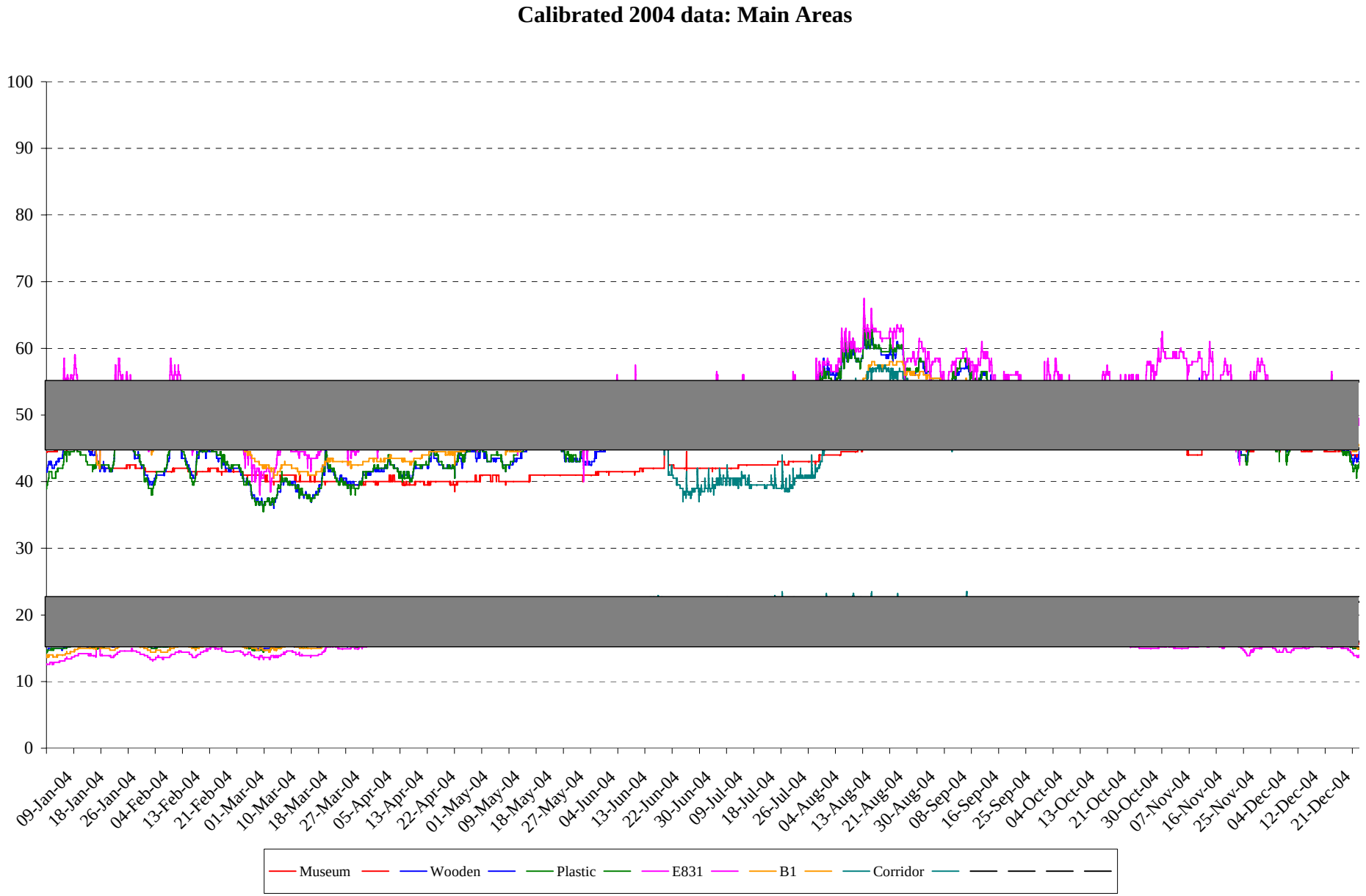

Figure 41 Calibrated data 2004: Main Areas, Murchison House

3.2.1.1 EXTREME AREAS

The target bands for the temperature and humidity in Figure 40 have been greyed out to enable those readings that are out-of-limit to be viewed more easily. It can be seen that almost all the humidity reading for the NE Corner are higher than suggested in *Doughty & Brunton* (1990).

The sharp drop in values noted in January is due to the logger being moved to another location during the calibration period. A similar drop for the same purpose in June is not as obvious as the background readings are closer to the grey band and therefore hidden.

The NE Corner line is almost entirely overwritten by that for the SE Corner from mid-September, showing that although there are a few small divergences on occasion, there is not a large difference between the readings obtained, on an annual scale. This was not altogether unexpected as the loggers are very close, within a metre of each other. However on a monthly scale it can be seen that there is a difference in the two locations, Figure 42.

This is an area that will be monitored closely as this corner was the subject of a study in 2003 that showed there was water ingress through damaged pointing. It was hoped that an improvement in the environment would follow the building works that were carried out after the 2003 study, however this has not been the case. It could be that there is still an element of residual moisture in the cavity causing the higher than normal humidity readings, not only on a localised level but also affecting the entire store.

The data for the Entrance cabinet shows a warm, dry environment. In fact this is the only logger that has temperatures **above** the maximum over a regular period. This is most likely due to the close proximity of an electric heater and that one wall of the area is fabricated entirely from sheet glass, which offers no protection from solar gain. Only robust specimens are put on display in this cabinet.

3.2.1.2 MAIN AREA

Greying out the in-limit data for the Main Area shows that for eight months of the year the temperature in all of the stores lies within the target bracket and most of the readings show that most of the loggers are within the bracket for all of the year with only two or three only slightly lower than the minimum for between two weeks and 3 months of the year.

Given that all the loggers are within the 45-55^{o}C bracket from mid-March to the end of the year, other than a slight dip in one area, is I think, very encouraging.

Unfortunately, the humidity in most of the areas is either lower or higher than the limits recommend for collections of this type for a large portion of the year. There is no obvious reason that this should be the case as what little external data we have, Figure 50, shows that the period was not significantly different to 2003.

What can also be seen from the trends is that all the loggers show increased humidity, albeit to a greater or lesser extent and with a lag, at approximately similar times. Once again, comparing the results to 2003, this shows that the different stores are experiencing increased humidity from external influences.

As with 2003 the encouraging aspect of the temperature graphs is that there are no sudden, dramatic rises or dips recorded. Any changes occur over a period of days and are generally small increases. The obvious contradiction of this the NE Corner, which appears to be more affected by alterations in the temperature than the other locations.

3.2.1.3 Discussion of Bar Chart Data

Figures 47 & 48, provide a summary of Figures 43 to 46 with Figure 49 providing the simplest breakdown of the 2004 data, showing the percentages of the data recorded lying within the target intervals.

These charts show that there is an improvement in the percentage of RH data within the 45-55% bracket in half of the areas; Wooden, E831 and NE Corner. This is interesting in itself as these localities are in two different stores and cover the spectrum of environments, i.e. a wooden tray, a plastic tray and an open area. The slight improvement in the humidity at the NE Corner could be related to the adjustment of the logger position to allow the comparison between the two walls discussed in a previous chapter. Why the two remaining trays should show an improvement in the humidity level and not the others cannot be easily explained and should not be taken in isolation.

Examining the temperature data provided in Figures 47 & 48 could offer some explanation: all the areas record an increase in the overall temperature of the stores, as shown by the increase in the percentage of readings recorded between 16^{o}C and 22^{o}C and, in one case, greater than 22^{o}C. The warmer air could be the source of the increased humidity and the composition of different sample trays the reason that the change varies from logger to logger.

Excluding the NE Corner for which an explanation has already been discussed, the loggers showing improved humidity readings both have lids, which may be providing a buffer preventing the ingress of the warmer, damper air.

Although the Museum tray is not only covered but also housed within a wooden cabinet it also records an increase in humidity, which would not be expected if one were to accept the explanation above on face value. However, the secure seal of the tray and the cabinet doors could be the significant factor in this case. The secure cover and closed door may be creating a mini-environment allowing the air to be retained in the tray and as the tray heats up the, slightly, damper air cannot escape, thereby raising the humidity. However, as the humidity does not rise above the maximum it is not too great a concern at this stage, of greater concern is the increase in the time the readings are lower than suggested. This area will be monitored more closely and changes made throughout the year in an attempt to improve the environment once again.

Following on the successes from 2002/03 it has proven to be more difficult to improve the environments in the storerooms by simple, inexpensive means.

Any improvements gained in the future may have to be more invasive and therefore more expensive. The provision of either heating, or humidifying/de-humidifying equipment is not a step to be taken lightly as it is disruptive and expensive to install and incurs ongoing maintenance and running costs.

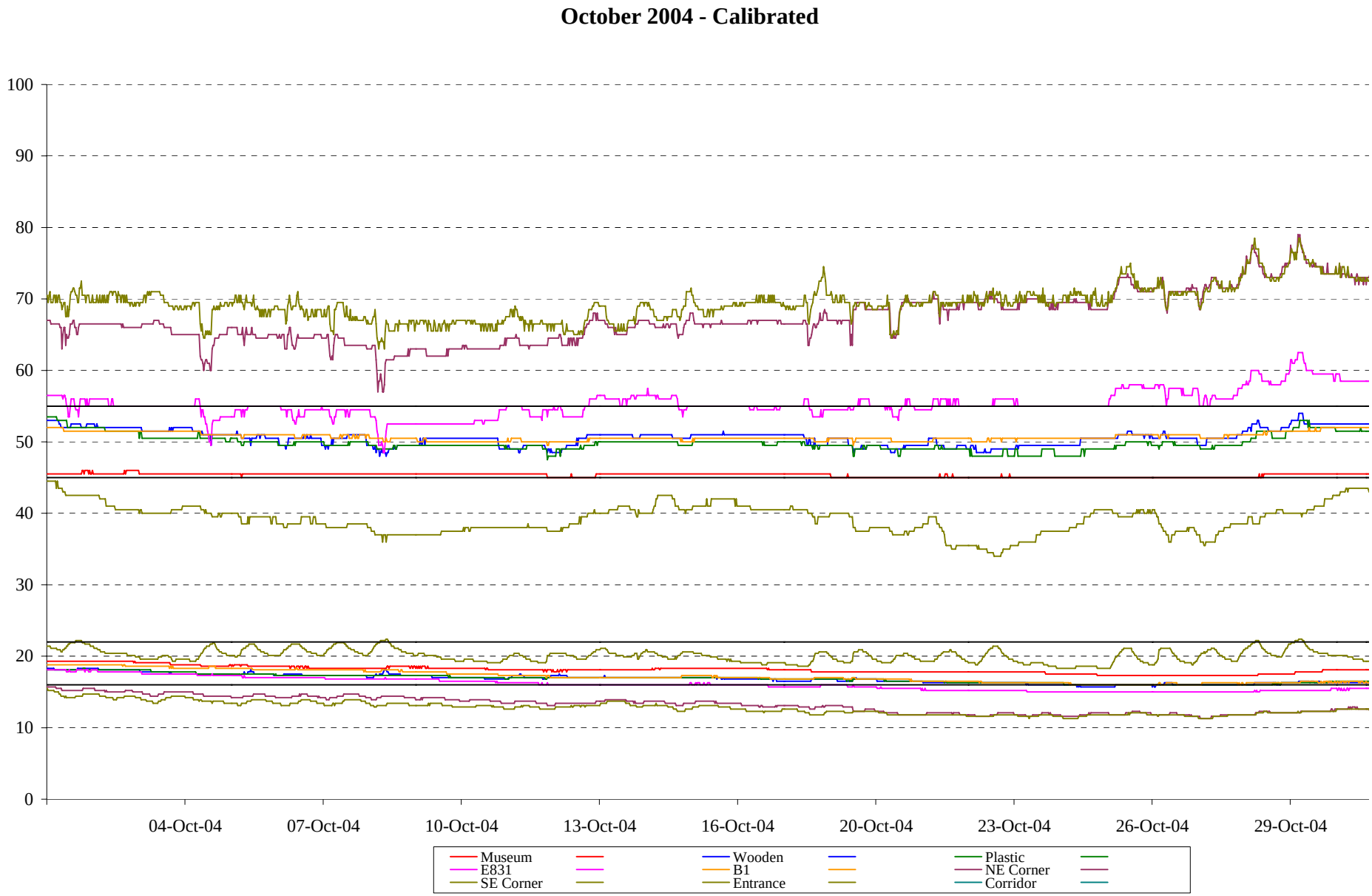

Figure 42: October 2004, Murchison House

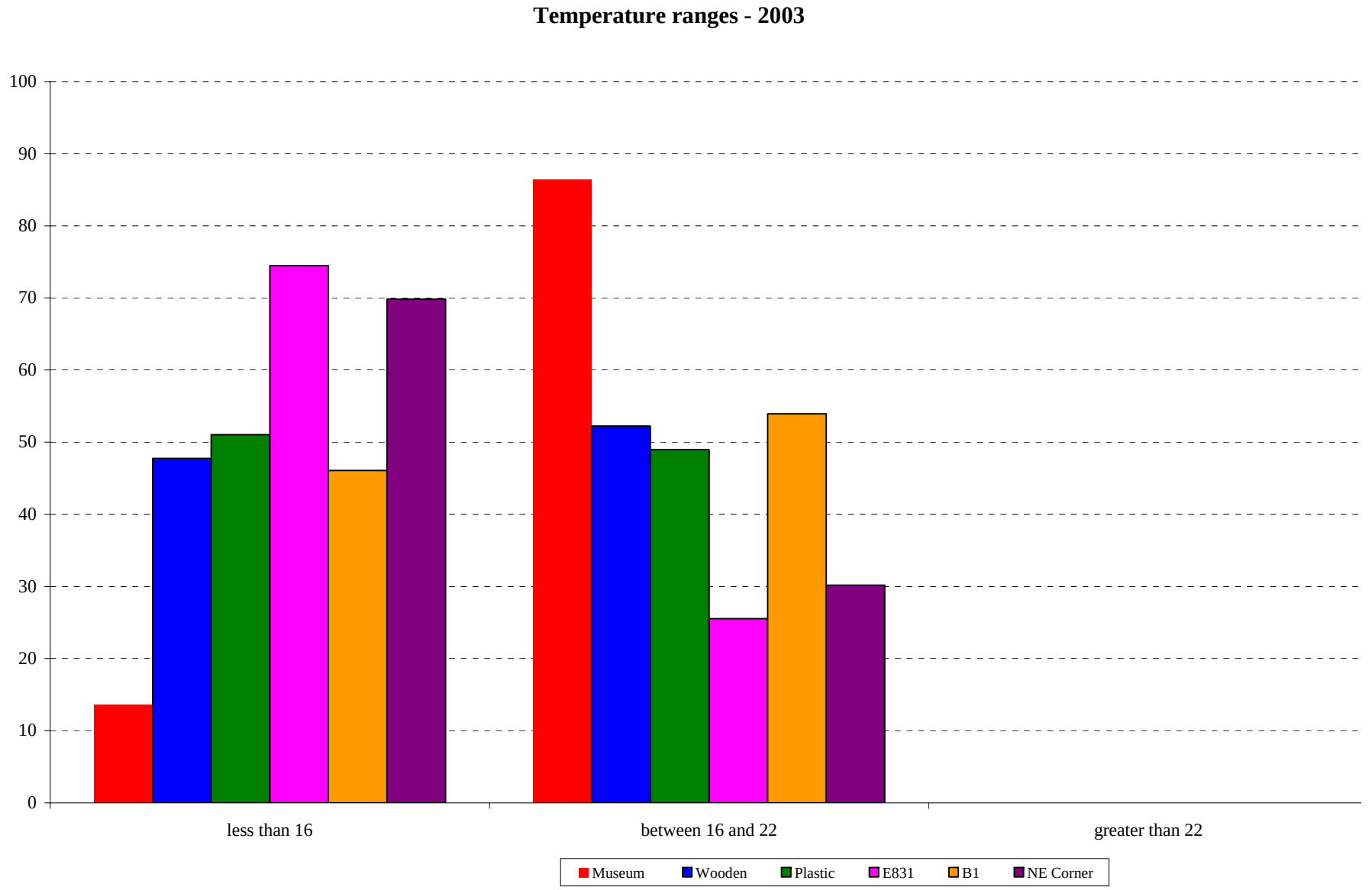

Figure 43 Temperature Ranges 2003

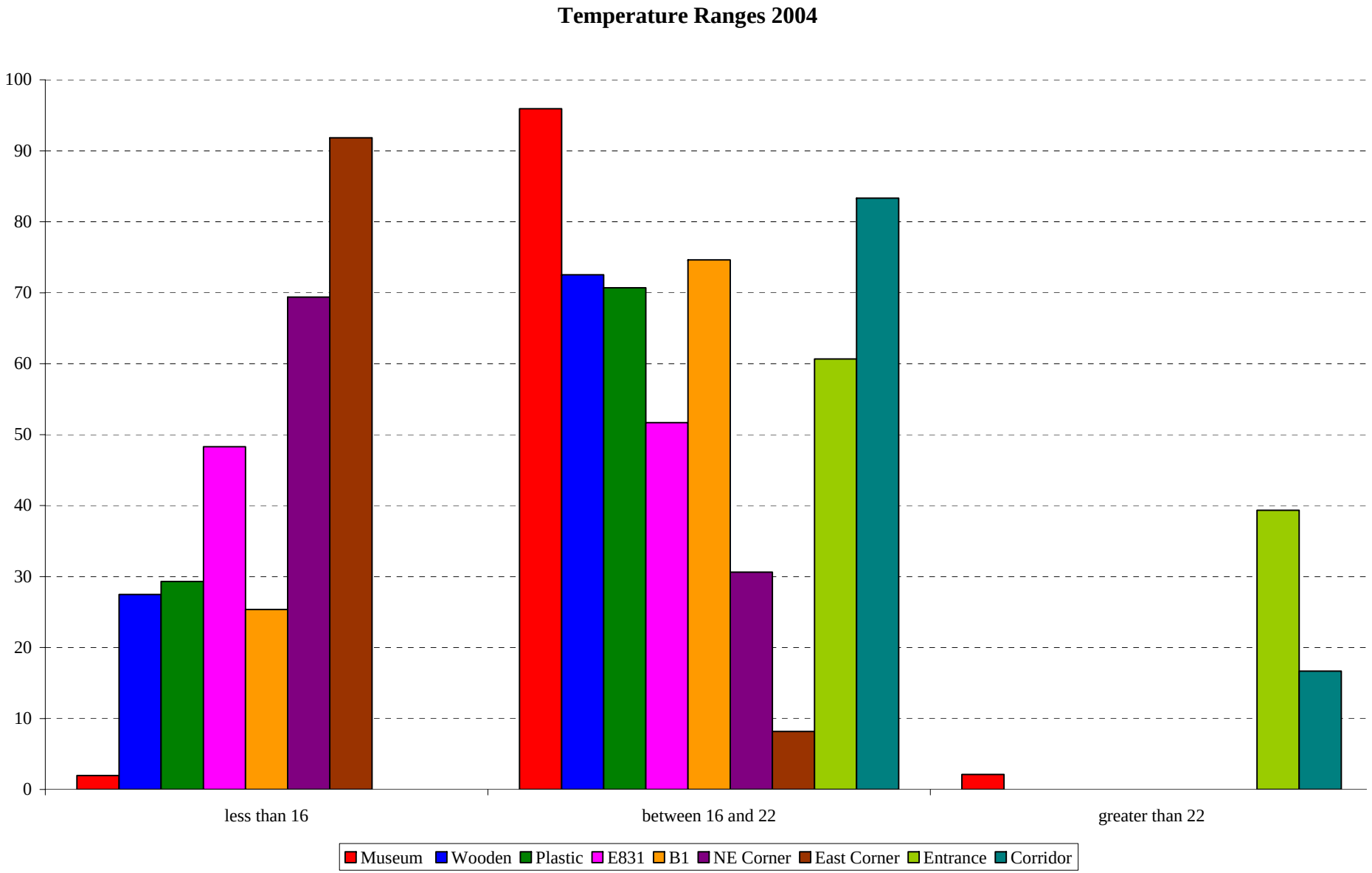

Figure 44 Temperature Ranges 2004

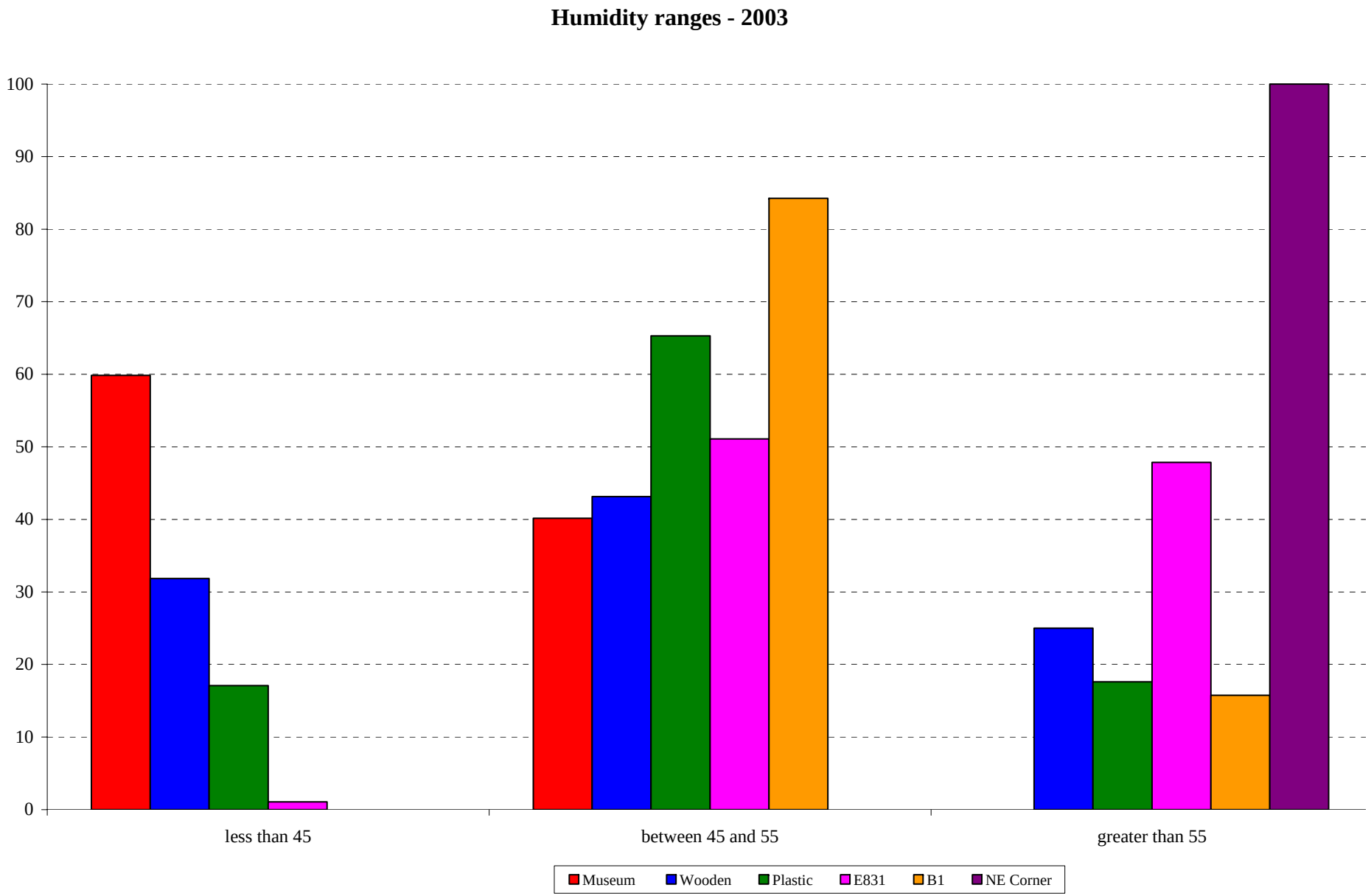

Figure 45 Humidity Ranges 2003

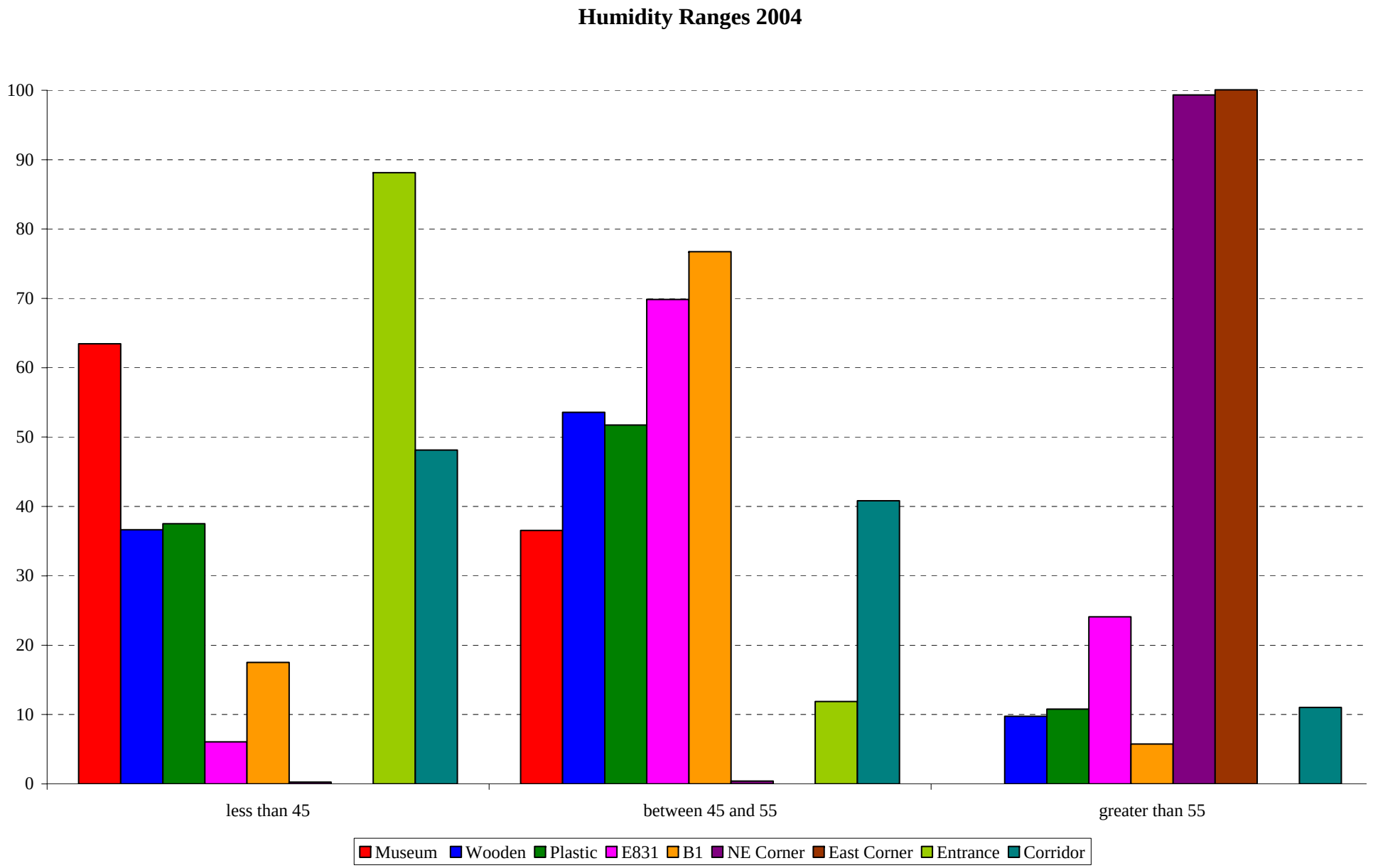

Figure 46 Humidity Ranges 2004

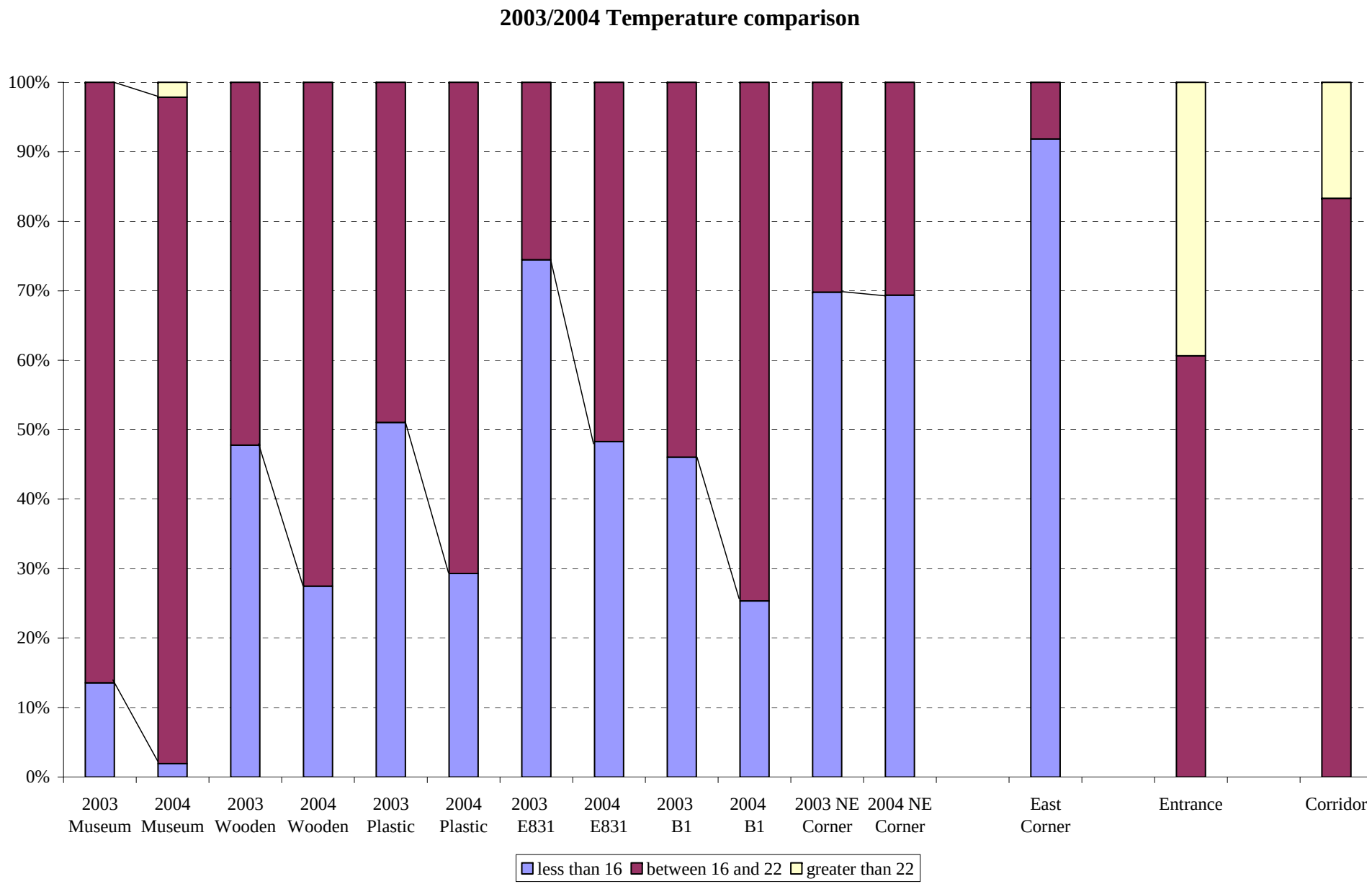

Figure 47: 2003/2004 Temperature comparisons, Murchison House

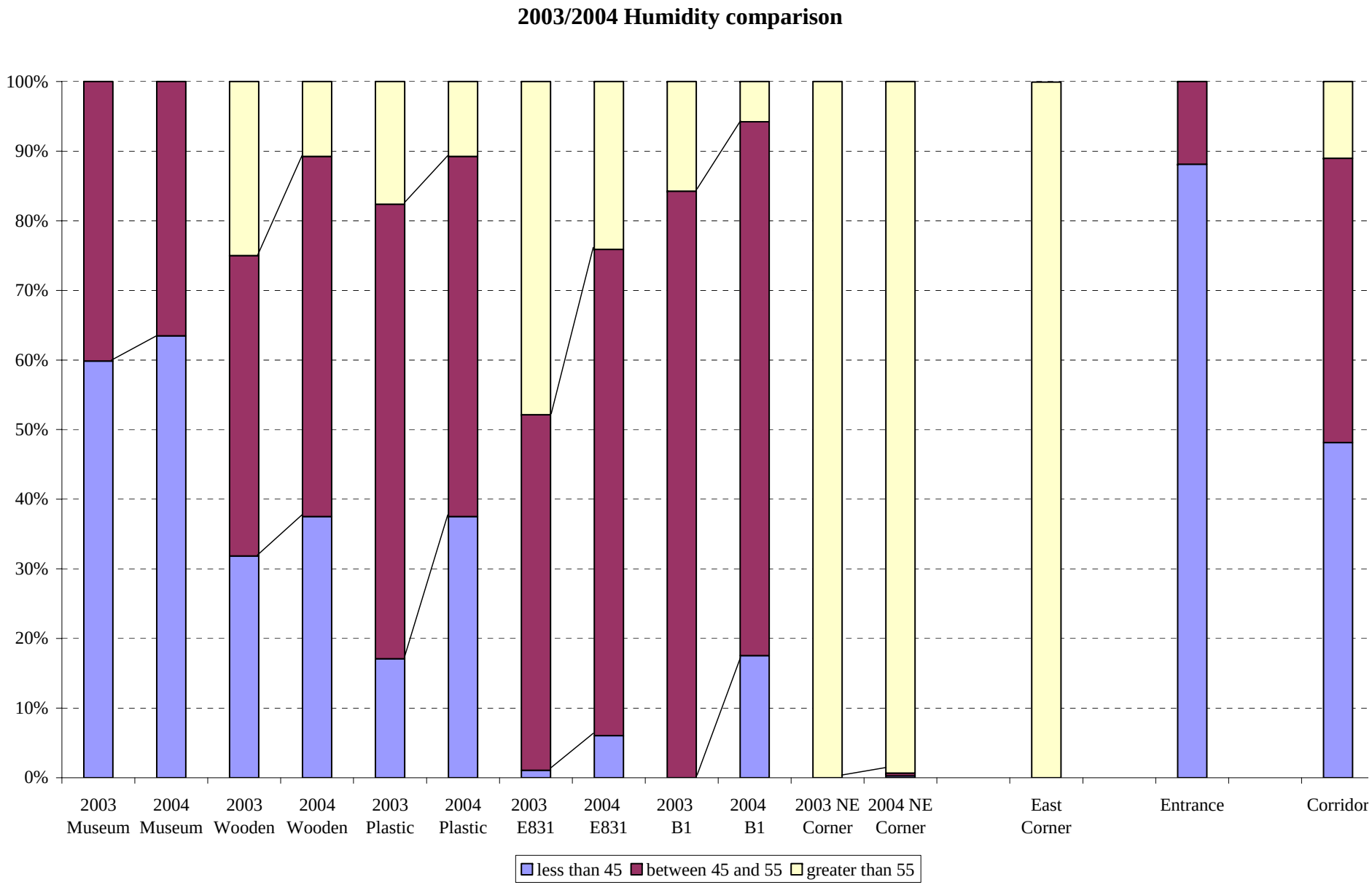

Figure 48: 2003/2004 Humidity comparisons, Murchison House

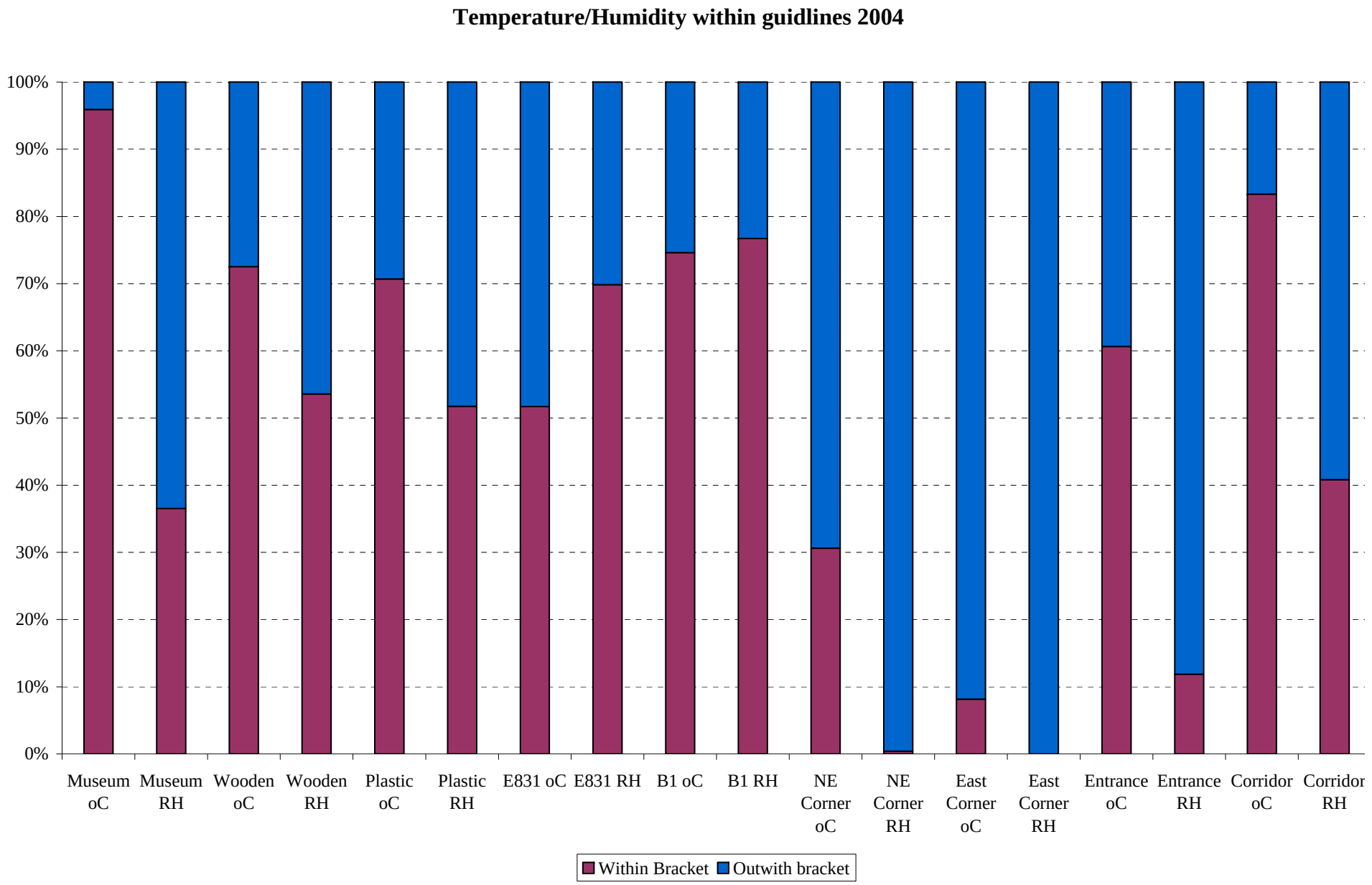

Figure 49: 2004 Temperature/Humidity target success breakdown, Murchison House

3.3 ANNUAL WEATHER DATA 2004

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 on a daily basis.

At present, the computer is a development machine and has a propensity to crash. During these periods of 'down-time' data logging is not performed.

Unfortunately due to staffing problems monitoring of the equipment was not carried out as frequently as in 2003 and as a result the external data for 2004 is sparse and incomplete.

This situation will hopefully be resolved from the second quarter of 2005 as the equipment will be transferred to Corporate Collections and Tulloch will take responsibility for both the equipment and the data download. The inclusion of a 'real-time' monitor should also result in a more rigorous data quality control and interrogation programme.

3.3.1 Annual Weather Discussion

The lack of weather data is disappointing as it was hoped to allow comparative discussion for the more extreme areas and possibly identify reasons for fluctuations in the temperature and humidity.

The lack of external data for the majority of the year unfortunately reduces any worthwhile discussion on the effect the weather may have on the internal measurements. As has been stated above it is hoped that this will not be the case for 2005.

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

To allow this observation to be undertaken easier a trend line has been included in the external data graph.

The weather graph for 2004, Figure 51, has been provided as a transparency to allow it to be placed over the annual data, Figure 39, Calibrated data 2004 and Figure 50, Weather 2003, for comparative purposes.

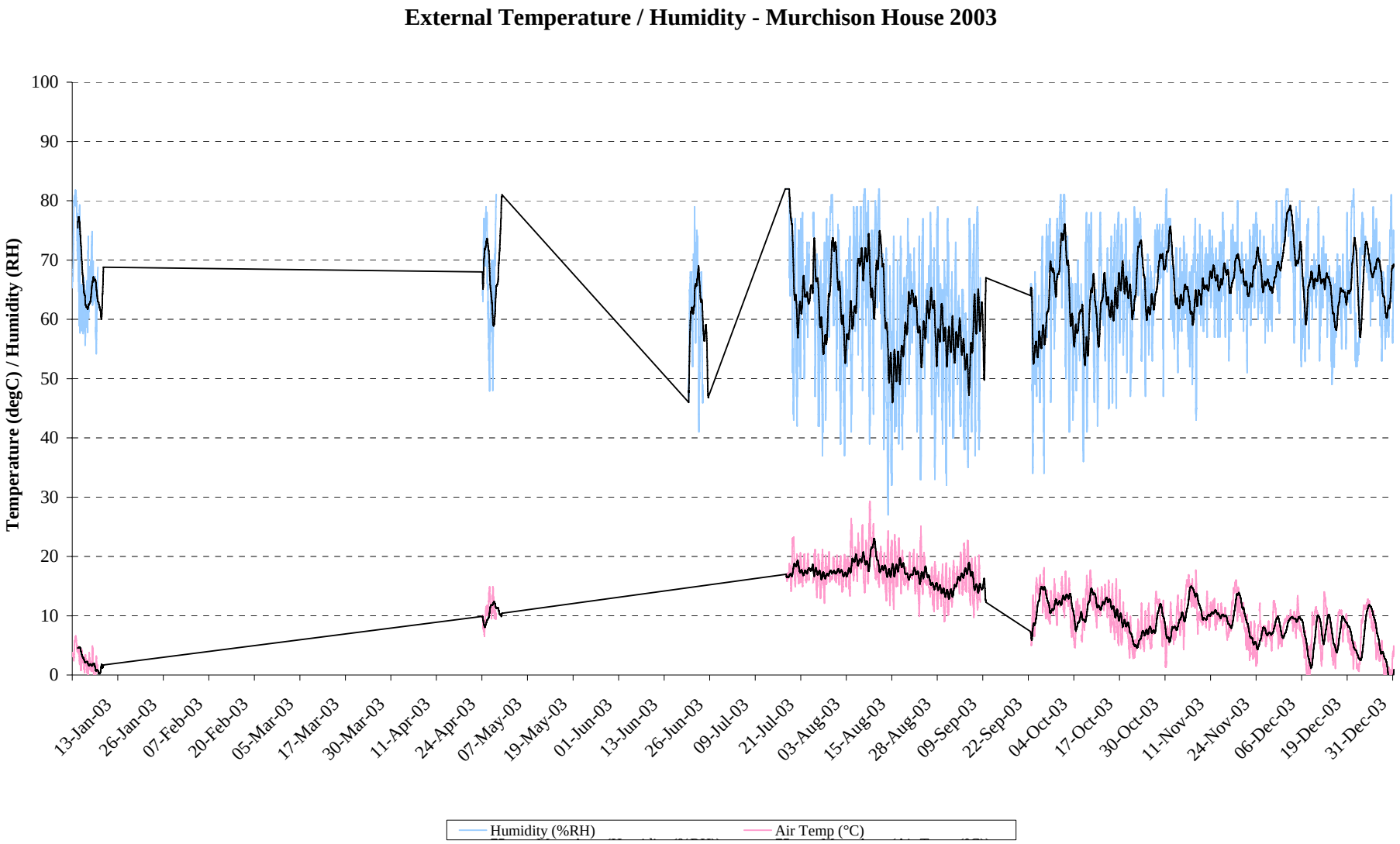

Figure 50: Weather 2003, Murchison House

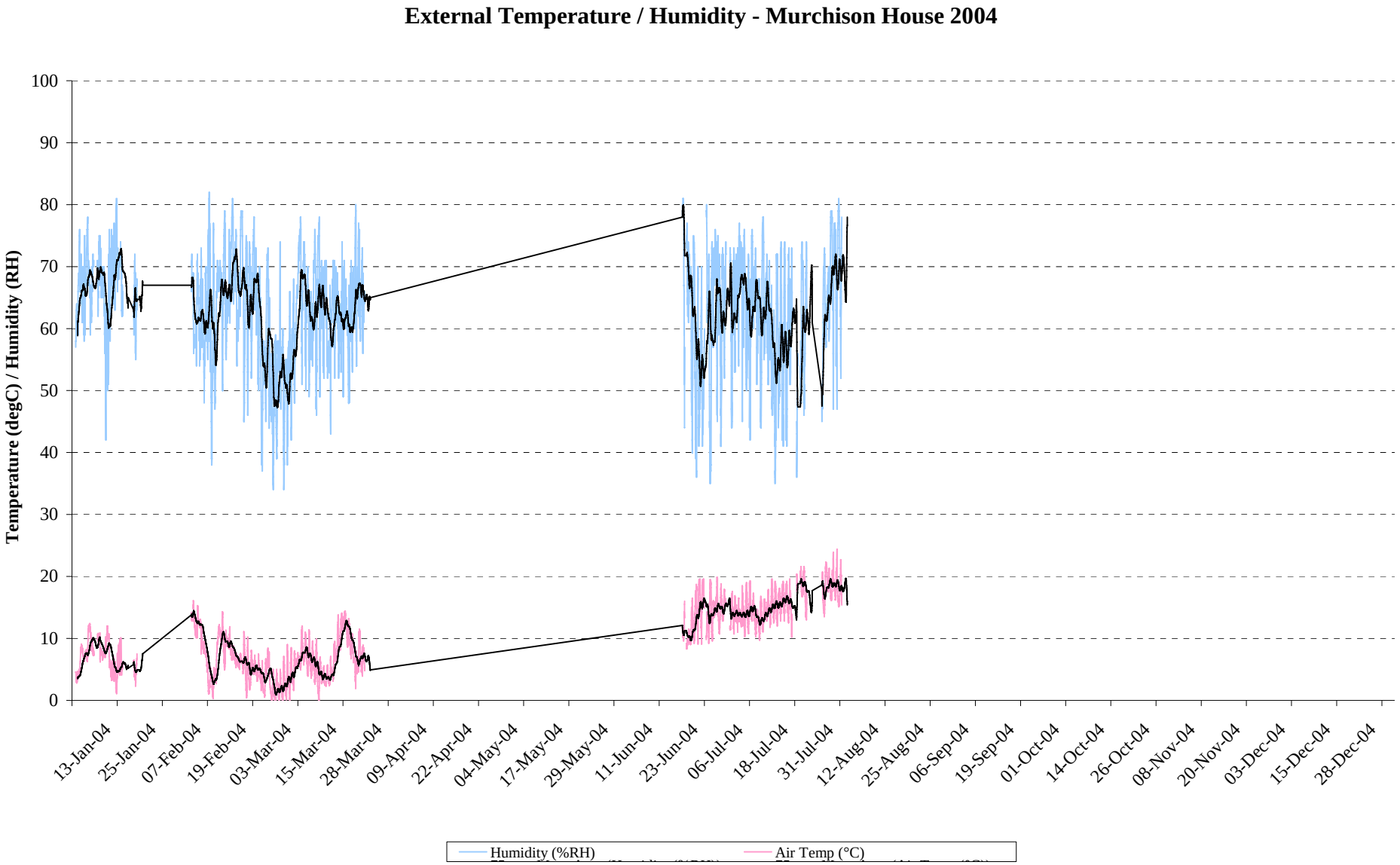

Figure 51: Weather 2004, Murchison House

3.4 MINI PROJECTS

2004 has been a year of consolidation and review of steps taken to improve the environment in the storerooms during 2003 and, using new loggers, monitoring a variety of additional areas.

The 'mobile' loggers have been used to monitor the environment in display cabinets in corridors and supplement existing loggers in storerooms.

It was pleasing to note that there were no events such as the one in 2002 which recorded a steep rise in the humidity over a few hours, *Shepherd & Tulloch, 2004,* and that the monitoring of the various storerooms appears to be having a positive effect on these areas as it not only brings issues to the attention of staff more readily but staff awareness is also heightened as a result of this programme.

The main 'Mini Project' currently in operation at this time is the evaluation of the area noted as a 'problem corner' during 2003. This area underwent remedial building work to rectify the high humidity issue and it was hoped that during 2004 we would see a decrease in the humidity as a result. Unfortunately this has not been the case.

A second logger was installed in the location to examine the difference between the loggers at two slightly different positions. This second logger has shown that there is a difference between the two locations, as noted in Figure 42. The data from these loggers will continue to be examined and used to formulate a strategy for 2005: this could include the installation of humidifying/de-humidifying equipment or invasive building works such as the removal of brickwork.

3.4.1 Results of 2003 Mini-Projects

3.4.1.1 DAMP METER

It was suggested in IR/04/032 that a damp meter could be purchased to check the amount of moisture in wooden boxes and brickwork. Unfortunately it has not been possible to obtain an economic monitor suitable for this purpose. New equipment being brought onto the market will be monitored and a purchase made if appropriate.

This was not carried out during 2004 and will be carried over to 2005.

3.4.1.2 MONITOR DIFFERENCES IN OPEN AND CLOSED AISLES

All of the racking in the Petrology store and most of the racking in the Palaeontology store is high density mobile racking. The racks are pushed apart by means of hydraulic rams, opening one open aisle and closing another.

It is presumed that the movement of air around trays alters as aisles are opened and closed. What is unknown at this time is what effect this has on the specimens in the trays.

When more loggers are available a comparative study between two adjacent aisles will be carried out. 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.

This was not carried out during 2004 and will be carried over to 2005.

3.4.2 Future Mini Projects

3.4.2.1 Damp Meter

It was suggested in IR/04/032 that a damp meter could be purchased to check the amount of moisture in wooden boxes and brickwork. Unfortunately it has not been possible to obtain an economic monitor suitable for this purpose. New equipment being brought onto the market will be monitored and a purchase made if appropriate.

3.4.2.2 Monitor Differences in Open and Closed Aisles

Mobile racking will be monitored to investigate the difference, or otherwise, of the environment in open and closed aisles. 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 for some months in order to determine if the poor environment in this area can be associated with the damaged pointing identified in 2003.

A de-humidifier will also be placed in this area and the environment monitored to determine if any changes are perceptible. This may establish a plan of action for the future of this and other similar areas.

3.4.2.4 Trial of Moisture Buffering Material.

A moisture buffering material such as 'Art-Sorb' will be purchased and placed in selected trays with loggers to evaluate its efficacy for our purposes and in the environments found in our storerooms.

3.5 RECOMMENDATIONS FOR EDINBURGH

The recommendations laid down for 2004 will continue as they have proved to be robust. The loggers in place will remain and the present 'mobile' loggers 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.

As stated above a damp meter will be purchased at the earliest opportunity to allow the monitoring of moisture in wooden boxes and brickwork, this may assist in the discovery of pyrite decay or efflorescence, or identify trays where the environment would allow such decay to occur in the future.

Gathering data of this type will allow a record of measurements to be built, increasing our knowledge of the environments of the stores and the trays in which samples are stored. This in turn could allow us to identify conditions where specimens are at greatest risk and take action to reduce, or stop, deterioration occurring before it has advanced too far.

It is of advantage to both projects that we work closely with Facilities Management to identify shortcomings in building fabric and arrange repairs. This proved particularly successful in 2003, continued in 2004 and is vital that it continues.

4 Conclusion

4.1 CONCLUSION FOR KEYWORTH

The continuation of the environmental monitoring programme throughout 2004 has shown that most of the locations monitored within Corporate Collections are often within the acceptable recommended parameters for the storage of such geological material types. This is particularly true for most of the areas that have been monitored during previous years.

There are some areas under the Corporate Collections control have only been monitored on a short-term basis, such as the conservation laboratory, core store corridor and museum library. During these periods they have not met the recommended parameters. Further monitoring throughout the coming years will be needed to allow further investigation and discussion will need to be made, depending on the outcome of this research.

Other areas monitored over a short-term included magnetic tapes in the tray store, and the cold store. These areas provided satisfactory results; however ongoing monitoring would be beneficial in assessing the suitability of these areas over a long period.

Monitoring has been useful in providing the necessary data to assist with any assessment of material affected by high humidity levels, resulting from water leaks within the museum and the core store corridor. This has shown that as a result of maintenance being carried out to rectify these problems, the situation in which material is stored has improved.

As we had monitored parts of the NGRC in 2003, it was beneficial to continuously monitor this area during 2004, when monitors became available. As BGS is recognised as a Place of Deposit by the National Archives, and the documents held here are of such importance it was deemed necessary that monitoring should be used to assess the suitability of this storage area. As a result of this it was recommended that the Library strong room should be included within this monitoring programme, however this only commenced during November 2004.

As a result of monitoring the NGRC (from June 2004), we have discovered that this area is not presently providing a suitable environment for the storage of these records. However if documents on parchment or vellum are not present then the NGRC strong room can provide a reasonable environment for other paper documents with regards to humidity levels. Temperature levels within this area need to be lowered to within the recommended parameters, thus making this area ideal.

The library strong room seems to provide acceptable conditions in terms of temperature, however humidity within this area must be improved in order to correctly store any historical records held on parchment or vellum. If such materials are not present, then the current conditions are reasonable, but further monitoring would be necessary to confirm this.

4.2 CONCLUSION FOR EDINBURGH

The Collections are housed, in the main, in rooms ill suited and under equipped for the task.

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.

The programme of monitoring the temperature and humidity is vital to the safe keeping of the specimens.

The heightened awareness of staff and the results from the monitoring programme has proved to be valuable in identifying defects to the building and working practices that could detrimentally affect the Collections; repairs have been made and working practices updated which has led to an improvement in the conditions in the rooms concerned.

A number of improvements have been made and have provided positive benefits to the environments within the storerooms. 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 current system and suite of loggers, meters and other recording instruments should be augmented by the purchase of additional loggers and damp meters.

Without a high level of expenditure on air-conditioning equipment this is the best way in which to monitor improvements to the storerooms. However, it may be that further improvements to the environment within the stores will only be possible with the addition of such equipment or building works.

Inexpensive alterations will be taken in conjunction with the local Facilities Management team and, if it is thought necessary, additional works and equipment discussed with higher Corporate Collections/Information Management and Facilities Management managers.

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.

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.

Six folders: -

30 Minute Extracted Data

- 19 sub folders for each locality monitored during 2004. All data calibrated converted to GMT where necessary and extracted to every 30 minutes.

Calibrated data from 2003

- Calibrated data used from 2003

Calibration Data

- Calibration period data in both lcf and csv format and Thermohygrograph data
- Grouped data for both prior and after the calibration period.

Raw Data in csv format

- 158 Sub folders, for 2004
- Raw data in csv format, for each monitor number including Thermohygrpgraphs and the weather readings.

Raw Data in lcf format

- 15 Sub folders for 2004
- Raw data in lcf. Format, for each monitor number including Thermohygrpgraphs and the weather readings.

Yearly Histogram data 2004

- Yearly histogram data for the main areas during

Appendix 3 Edinburgh Data

Adobe® Acrobat® version of this report.

Four folders: -

2003

- 2003 Data.xls (Calibrated/GMT adjusted data for the year in MSExcel format).
- Bar graphs.xls
- Calibration.xls
- NE Corner.xls

- Converted Files
  - 12 folders containing Raw data in Comma Separated Value (csv) format (readable by MSExcel).
- Logger files
  - 12 folders containing Raw data in original format as downloaded from loggers (lcf format).
- Met Data
  - RE weather station.txt (text file explaining the data format of the files).
  - 2003
    - Met data 2003.xls (Calibrated/GMT adjusted data for the year in MSExcel format).
    - 9 folders containing data from Weather Station in original format (Raw) and MSExcel format (Splits).

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
  - 12 folders containing Raw data in Comma Separated Value (csv) format (readable by MSExcel) in monthly folders.
- Logger files
  - 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.mdb - Weather station data

Met Data

- Met data 2003.xls (Calibrated/GMT adjusted data for the year in MSExcel format).
- Met data 2004.xls (Calibrated/GMT adjusted data for the year in MSExcel format).

(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

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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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