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STRATEGIES AND CLIMATE HOPES FOR COLLECTION CARE AND ENVIRONMENTS AT THE NATIONAL MUSEUM OF THE PHILIPPINES

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ABSTRACT

Tropical climates pose higher risks to museum collections and people, if not understood and managed. The higher temperatures and humidities experienced by memory institutions situated in the tropics, has long been a challenge as organisations engage with collection care beyond the universally claimed environmental controls and climate change. This study examines the influence of climate on collections belonging to the National Museum of the Philippines and the interpretation of material changes and collections at risk. Informing the paper is environmental data recorded from 2013 to 2024 from several floors and galleries from the National Museum of Anthropology and National Museum of Fine Arts, as well as the experiential engagement with the collection over the same period, to examine the dynamics of change in urban, tropical climates, the culture of museum care and sovereignty. Micro-organisms are regularly identified signalling high risk to the collections, museum staff, and visitors; and mechanical failure of composite collections. Mechanical systems are intermittently used during the day and off at night, while periods during the pandemic when air conditioning was not in use, is a chance to examine energy consumption, passive climates and whether this is a real option in the tropics. Having the opportunity to experience, rethink and reflect on collections in the tropics, is creating strategies for collection care in hot, humid climates, and more broadly has increasing relevance for collections outside the global south as wider discussions on museum environments and de-centralised goals are being embraced.

KEYWORDS: tropical climate, Philippines, collection care, mould in collection, challenge led

1. INTRODUCTION

To preserve heritage collections, the impact of risks is commonly grounded by the ten agents of deterioration namely: physical forces, fire, dissociation, thieves and vandals, water, light (ultraviolet and infrared), pests, pollutants, incorrect temperature, and incorrect relative humidity (Canadian Conservation Institute, 2017). Half of these risks are categorized by Maekawa, Beltran and Henry (2015, pp. 19-20) as particularly damaging to collections and heritage buildings located in hot and humid climates. Although the cumulative impact of these agents – light, pests, pollutants, incorrect temperature, and incorrect relative humidity – are likewise a risk to collections in temperate regions, in tropical climates their magnitude of risk is much higher with expected changes in 1-10 years (Heritage Collections Council, 2002, pp. 10-15).

As a general rule based on the Arrhenius equation, Feller (1994) highlighted the increased rate of reaction as temperature rises and Michalski (2018 cited in ASHRAE (2019) notes that rates of chemical decay, benefit from lower temperatures, and a 5°C drop will double the lifetime of collections (Maekawa, Beltran & Henry 2015, p. 31). Further, the agents do not behave alone but 'act synergistically with other modes of deterioration, supporting mould growth, insect activity, acidic deterioration by pollutants, and photochemical degradation' (Grech et al., 2019, p. 420). An example of tropically aged materials is shown with regards to oil paint, where within 10 years, surfaces were matte, poorly adhered to the substrate and friable, but the same sample set aged in temperate climates, remained intact and glossy (Grech et al., 2019). This is just one example of controlled material experiments in tropical climates and the faster degradation pathways which impact on the magnitude of risk for collection care.

However, based on work of the National Museum of the Philippines (NMP) with national, regional and Church heritage, Tse, Labrador and Balarbar (2018) have concurrently argued for an expanded view of the ten agents of deterioration to rather engage with the four agents of conservation and the relationships of object, people, time and place. This has arisen out of the challenge led experiences of collection care in hot, humid climates, and situated thinking around museum knowledge systems and governance in the Asia Pacific region, and could be viewed as more socially, economically and environmentally sustainable for the NMP (Tse, 2023). As an example, Figure 1 illustrates the historic outdoor climates in Manila from 1961-2021 (Port Manila weather station) that average between 27-28°C up to 1986, and then recorded as over 28°C from the late 1980s and 75%RH (PAGASA, 2023). As such, collections are likely to have experienced the dynamics of higher temperatures and humidities beyond typical museum standards which has necessitated more creative and collective conservation actions (Barns & Labrador, 2014). Challenges are further compounded by the frequency of natural disasters, with the Philippines ranked as the fourth affected country by extreme weather events from 2000-2019 by the Global Climate Risk Index (Eckstein, Künzel & Schäfer, 2021).

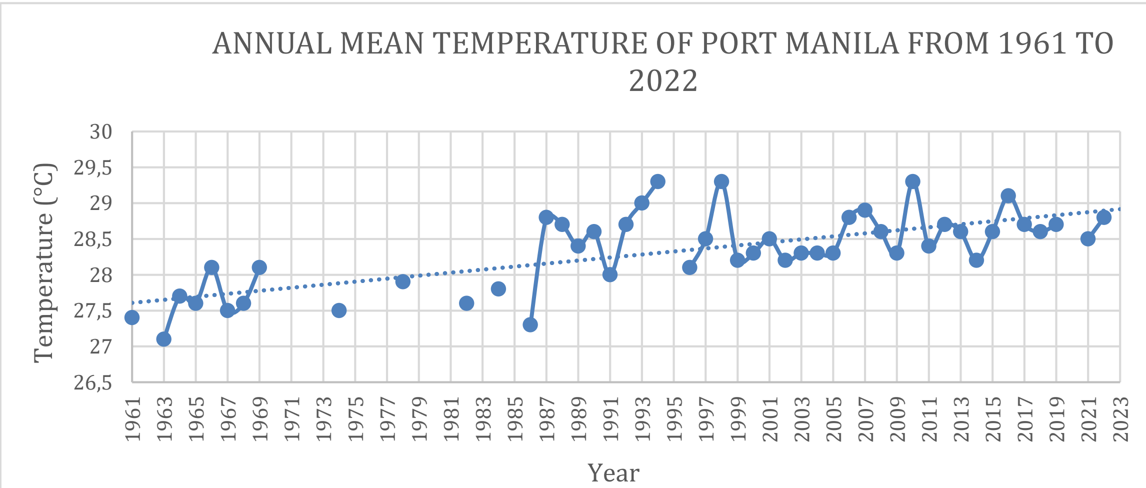

Figure 1. A graph of the annual mean temperatures at Port Manila collected from 1961 to 2022. Data Source: Climate and Agrometeorological Data Section (CADS), Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA).

Clearly, these climates illustrate the challenges ahead of NMP and lay outside typical museum standards, like the Bizot Green Protocol (2015), the AICCM Environmental Guidelines (2022), and ASHRAE (2019). Further, conservation practice is, in the main, informed by research undertaken in Europe and North America, and while useful and reliable references, these may not be directly applied to regions with different climates like in tropics. Figure 2 from Taylor (2023) for example, shows how Manila's climate compares to eleven other countries worldwide, and collection climates and behaviour is unlikely to be the same. To add, there are just a few publications on the management of environmental conditions and collections in Philippine museums, examples include papers by Villanueva, Páez Cure and Brokerhof (2023); Barns and Labrador (2014); and Tse et al. (2018). In effect, a deeper understanding of buildings and collection materials in the tropics, thresholds for climate care, and their human relationships is needed to frame the life expectancies of cultural records held in these conditions.

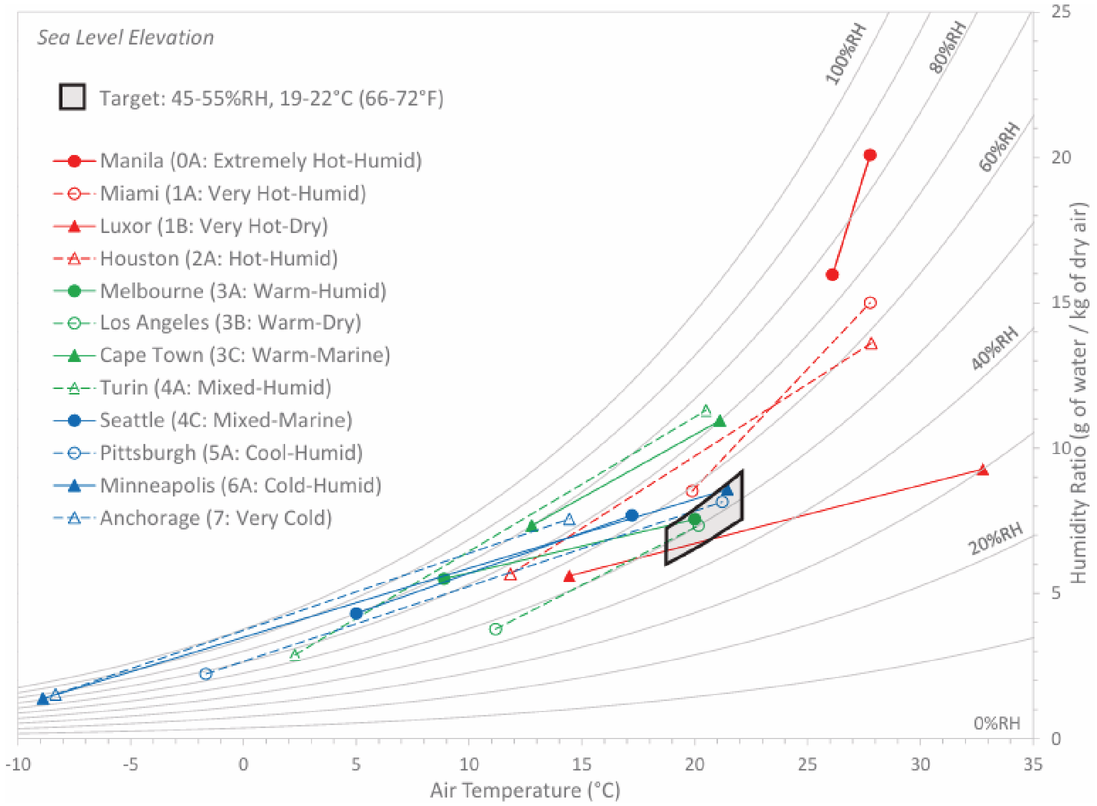

Figure 2. From Figure 6.1 in Taylor (2023), Managing collection environments: technical notes and guidance, illustrating Manila's climate compared to 11 other countries worldwide (© 2023 J. Paul Getty Trust)

Following the above mentioned challenges, this paper examines the museum climates of NMP's Anthropology (NMA) and Fine Arts (NMFA) Buildings; the gallery, building and external climates; the use of mechanical controls when on and off; evidence of collection changes; and collection care experiences. This is with the view to highlight the challenges and creative options to develop collection care processes and targets with reference to the NMP's own values and systems.

2. METHODS

Methods used are interdisciplinary generated from 1) recorded climate data, 2) interviews with NMP staff from building maintenance, collections management and the fine arts and ethnology divisions, 3) longitudinal technical observations of material changes, and 4) access to NMP institutional records such as historical climate data and the buildings energy consumption.

Table 1 shows the temperature and RH% data recorded with HOBO U14-001 and T-Tec 7_IC dataloggers[1] at various time periods between 2013 to 2024. The building power interruptions and HVAC failures from March to May and September to mid-October 2020 are also included. Data was obtained from the NMFA and NMA buildings before, during and after the pandemic, with the support of spot readings taken by colleagues when the museum was closed and NMP staff were on alternating work arrange-

[1] #HOBO U14-001 purchased on March 2020 with an accuracy of +/- 0.2C and +/- 2%RH, not recalibrated in this period.

*T-TEC 7-IC dataloggers purchased March 2017 with an accuracy of ±1 °C from -20 + 70 °C, not recalibrated in this period.

ments. Furthermore, there are some incomplete datasets from the environmental sensors due to technological problems and staff restrictions during the pandemic. Figure 3 illustrates the two NMP buildings, and Figure 4 the floor plans of the galleries and locations of the dataloggers as presented in Table 1. To identify the climate load on the building, the comparative performance of galleries, micro-climate display cases, and the impact of mechanical systems, psychometric and time series plots were produced based on the Getty Conservation Institute's 'Museum collection environment: technical notes and guidance (Taylor *et al*, 2023).

Table I. Periods of temperature and relative humidity data recorded from 2017 to 2021. Recorded with HOBO U14-001# and T-Tec 7_IC* dataloggers

Date / period examined	Building	Gallery Name	Location in building	Data logger location & type of logger * T-TEC or # HOBO	HVAC operations
6 Dec 2017 to 23 Feb 2019	NMFA	Gallery 2	2nd floor West facing	Middle of the room*	HVAC on Tuesdays to Sundays 8am-5pm only
10 Apr 2017 to 15 Jul 2018	NMFA	Stairwell	4th floor East facing	On ledge*	No HVAC
30 Mar 2020 to 3 Mar 2021	NMA	Rice Gallery	4th floor Southwest facing	Middle of the room#	HVAC on Tuesdays to Sundays 8am-5pm only, except on 30 March to 5 May 2020 and 4 September to 21 October 2021 due to HVAC failure
30 Mar 2020 to 3 Mar 2021	NMA	Hibla Gallery	4th floor Northwest facing	Middle of the room#	AC on Tuesdays to Sundays 8am-5pm only, except on 30 March to 5 May 2020 and 4 September to 21 October 2021 due to HVAC failure
30 Mar 2020 to 3 Mar 2021	NMA	Bangsamoro and Lumad Galleries	3rd floor Northwest facing	Middle of the room#	HVAC on Tuesdays to Sundays 8am-5pm only, except on 30 March to 5 May 2020 and 4 September to 21 October 2021 due to HVAC failure
30 Mar 2020 to 3 Mar 2021	NMA	Biyay Gallery	3rd floor East facing	Middle of the room	AC on Tuesdays to Sundays 8am-5pm only, except on 30 March to 5 May 2020 and 4 September to 21 October 2021 due to HVAC failure
8 Oct 2021 to 23 Sept 2022	NMA	Rice Gallery	4th floor Southwest facing	Middle of the room	HVAC on Tuesdays to Sundays 8am-5pm only
8 Oct 2021 to 23 Sept 2022	NMA	GAMABA Gallery	3rd floor Southwest facing	Inside a display case	HVAC on Tuesdays to Sundays 8am-5pm only


north

Figure 3. Main: The National Museum of the Philippines Complex in Rizal Park, Manila –The National Museum of Fine Arts (left front), the National Museum of Anthropology (middle), and the National Museum of Natural History (far back). Photographed using a drone by Jubal Kenneth V. Bernal, 2024.

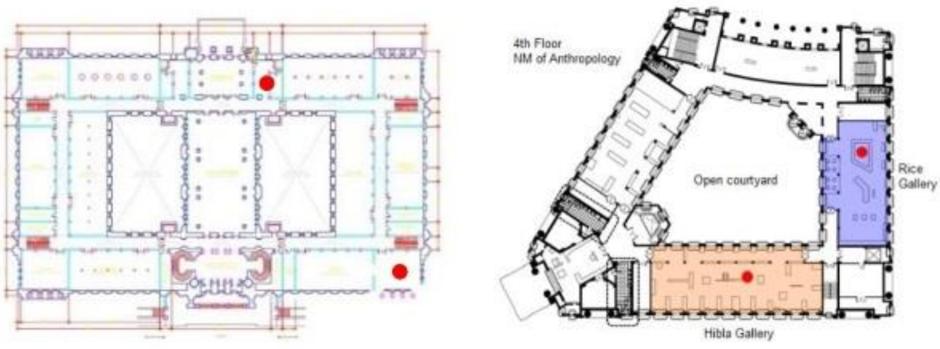

Figure 4. Plans of the buildings and floors where environmental recordings took place and red dots show the location of the galleries, Left: Plan of the National Museum of Fine Arts (left front in Figure 3), 2nd floor Gallery 2 (West), and 4th floor stairwell (East); Right: National Museum of Anthropology (middle in Figure 3), Rice Gallery (Southwest) and Hibla Gallery (Northwest). Not all the building floors, galleries and datalogger locations are shown.

Together a balanced and evidenced based analysis of climate targets relevant to the NMP and the tropics, dew point and biodeterioration thresholds, the applicability of non-mechanical and passive climates, and discussions of life expectancy of collections, could take place.

3. BACKGROUND

3.1 The National Museum of the Philippines

The NMP has three central museums located in Manila in view of each other: the National Museum of Natural History, the National Museum of Fine Arts, and the National Museum of Anthropology (Figure 3 above), which includes the Ethnology Division, the Archaeology, and Maritime and Underwater Cultural Heritage Divisions. All three are in historic buildings with the NMA built in 1918 (reconstructed in 1946), and NMFA in 1921 (then reconstructed in 1949). Apart from these three central museums, there are 17 regional, area and site museums under the management of the NMP (Figure 5) (National Museum of the Philippines 2023). In the future, there will be five more regional museums to be launched which will include one off-site storage facility as indicated by the green dots. Figure 4 shows the plans of the two buildings, NMFA and NMA, where environmental monitoring took place and the respective galleries examined (see the red dots). In Manila north of the equator, the south facing roofs have the higher solar gain and the north facing, the least. Given this, collection areas along the south facing walls are most prone to solar loads and are often the hottest and brightest.

The NMP has grown since the revision of its organizational structure and human resources (Labrador & Tauro, 2019). In 2016, it created 235 new job positions to a total of 568, many of which required higher entry level qualifications. The goal was to shift NMP's organizational structure more in line with a typical museum. Growth at this scale has brought about a culture of change and a rethinking of NMP's act which was revised in 2019, its functions and proactive engagement with its collections and communities (Republic Act No. 11333, 2019).

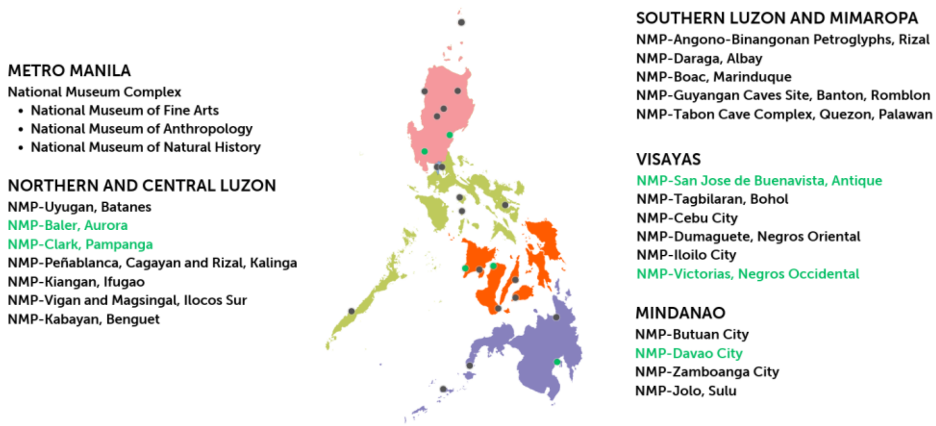

Figure 5. The National Museum of the Philippines central museums in Metro Manila and regional museums all over the country (highlighted in green are museums that are yet to be launched). Credit: Communications and External Affairs Section, Office of the Director-General, National Museum of the Philippines.

3.2 *Tropical climates*

The ASHRAE Standard 169-2021 classifies Manila to be in Zone 0A or in an extremely hot and humid climate zone which suggests that annual cooling loads are higher than the heating loads, especially when a building depends on air-conditioning in extreme heat and higher relative humidity (Henry, 2023). The Philippines in general has a tropical wet and dry season, and a tropical monsoon season which is split into a cool dry period from December to February, and hot dry period from March to May. The rainy season is from June to November (Philippine Atmospheric, Geophysical and Astronomical Services Administration PAG-ASA, 2023).

Like most countries globally, there is a general rise in temperature, and in Manila at least a 1°C has been recorded in the past 30 years as illustrated by the trend line in the historic annual mean temperatures from 1961 to 2021 (Figure 1) (Climate Monitoring and Prediction Section 2023). The Philippine Atmospheric, Geophysical and Astronomical Services Administration (Climate Monitoring and Prediction Section 2023) reports that temperatures average at 28.3°C in the warmest month of May, and highest average 85%RH in September. The Asian Development Bank reports that the Philippines is highly susceptible to climate tropical cyclones, floods, and heat waves, and they are becoming more frequent (Tse, Labrador, Scott & Balarbar 2018).

With respect to target climates for cultural collections in the tropics, the two most relevant guidelines for hot, humid climates are considered, the AICCM environmental guidelines (AICCM, 2022) and Australia's Heritage Collections Council (HCC, 2002). The AICCM environmental guidelines (2022) for humid climates recommend that temperature is between 15°C to 25°C and relative humidity levels from 45% to 65%RH but this may differ depending on an object's material and condition, and multiple short-term fluctuations of 5-10%RH should be addressed. The Heritage Collections Council (HCC, 2002) of Australia recommends that for museums in the tropics, the acceptable diurnal temperature levels are between 22°C to 28°C and relative humidity levels are from 55% to 70%RH. However, if these levels are unachievable for various reasons, the priority is to reduce RH levels to below the 70%RH biodeterioration threshold as well as reducing fluctuations in both temperature and RH if possible. Given that the HCC targets are the closest to the average temperatures and %RH of Manila and more comparable to the localized tropical conditions, they will be used as a guideline and reference point on the psychometric plots produced, to gauge where the NMP is currently in terms of environmental control. In this sense, parameters for collection loans from temperate to tropical climates are not feasible according to the Bizot Green Protocol (2015) or ASHRAE (2019) but could for useful for loans within the Asia Pacific region with similar climates and collections acclimatized to these conditions. Exposure to these higher temperatures and %RH targets, however, still has implications for thermal ageing, hydrolysis, the eventual life expectancy of the collections and reaction rates, as explained earlier.

4. RESULTS AND DISCUSSION

4.1 *The building, galleries and building operations*

Located in a tropical climate, heritage buildings like the NMP were originally designed to include natural ventilation, high ceilings, wide windows and central courtyards. But since the buildings were repurposed to hold cultural collections and welcome people, mechanical HVAC units were introduced to control temperature, ensure the long-term preservation of the collections and to make visitors comfortable. When the NMA was retrofitted in 1998, the centralised HVAC systems were composed of four units of 200-tonner chiller machines and various air-handling units (R. Dolorota, pers. comm., 3 October 2023). The NMFA has 249 individual units for each gallery. According to three NMP staff interviewed, every gallery and repository have at least one dehumidifier unit depending on the total volume of the room (M. Tauro 2023, pers. comm., 19 September; C. Valencia 2023, pers. comm. 23 June; R. Ureta 2023, pers. comm. 15 September). It is well known, however that heritage buildings have 'poor air control performance' because of the higher exchange rates from envelope penetrations through windows and doors (ASHRAE, 2019). Thus, the climate option to utilize non-mechanical controls is difficult to achieve.

Visitation to the NMP has almost tripled from 534,820 in 2015 to 1,689,007 in 2018 (Labrador and Tauro, 2019). In urban Manila with average temperatures of 28.3°C in the warmest month of May, human comfort is part of the visitor experience as people come in from the heat and seek refuge, much like visits to the larger shopping centres or hotels in Manila. Air conditioning in Asia is 'seen as pivotal to transformations in urban design and living' (Winter, 2013, p.517) and a signifier of work-place efficiency and attractiveness. In effect, air-conditioned spaces promote access and visitation to the NMP, while increased visitor numbers contribute to air borne contaminants and carbon dioxide levels. Essentially, a rise in air exchange rates increases energy use and running costs of HVAC systems. We can expect too that air exchange rates per person in the tropics, is calculated at a greater value because of the high body temperatures of incoming visitors compared to the cooler climates inside the NMP galleries.

The poor performance of NMP's heritage building, tropical location, and increasing visitor numbers, all point towards high operation costs for the mechanical systems. HVAC units subsequently contribute to a larger proportion of NMP's electrical bills even though they only operate in the daytime and are turned on at 8am until 5pm from Tuesday to Sunday, and off overnight and Mondays in galleries and collection stores. As such, energy bills for the NMA building from March 2020 to August 2023 were obtained to broaden our scope of knowledge and work more collectively with building maintenance. Figure 6 on the left, shows the total amount paid of PhP 42,825,555.57 when the maximum load is set at 1,904.00 kW, which is an agreed rate provided by the utility company to the NMP. Incentives or fee adjustments are incorporated in the bill when a power factor of 85% and above is achieved, which shows whether a building is performing efficiently (Cabugayan, Dichoso & Valencia, 2013, pp. 1502-1503). And likewise, failure to meet the 85% power factor means additional fee charges. The power factor is a measure of how efficiently power is used. When it is closer to 100%, power is used more efficiently, while a lower power factor demands extra power to operate electrical systems, thus requiring higher costs (Manila Electric Railroad and Light Company 2023).

Upon reviewing the bill, NMA's Guaranteed Minimum Billing Demand (GMBD) is set at 1,904.00 kW. This is the maximum load set forth by the utility company to its client in kilowatts (kW), and the demand charge used by a building is equivalent to the power rate per kilowatt-hour (kWh) multiplied by the constant GMBD (Manila Electric Railroad and Light Company 2023). In other words, GMDB is used as a multiplier to come up with demand and distribution charges, regardless of power consumption. Accounting for the load consumed, the maximum actual load for 37 months is only 924.70 kW which is almost half of the set GMBD as shown in Figure 6 on the left. It may then be possible to adjust the GMBD setting to 924.70 kW as shown in orange from 1,904.00 kW, and likewise prompt energy reductions for the NMP. Should further energy efficiencies to NMP buildings be incorporated, improvements to the power factor could also bring down costs. As such, evaluation of climate related risk points in the building not only benefit the collection, but acting on the risks and initiating facility upgrades and maintenance, can bring down costs through the incentives offered. This monetary savings can mean a realignment of the budget to economic sustainability and other important operating costs of the museum.

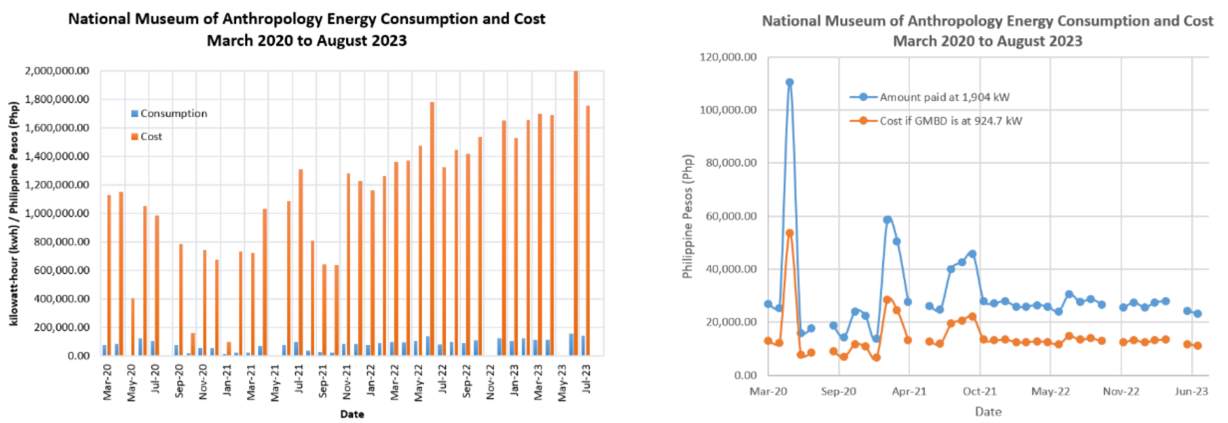

Figure 6. Left: Energy consumption and cost for the NMP from March 2020 to August 2023 in Php, Right: Compares the actual amount paid with GMBD at 1,904kW (blue line) vs the cost if the GMBD is set to 924.7kW (orange line).

4.2 Collection, access and care

Most of the collections of the NMP are stored in the three central museums because of their storage capacity. The NMFA includes fine and applied arts, built heritage and immovable cultural properties, and the NMA is dedicated to collections that examine the origins of the Filipino people, terrestrial and underwater archaeological collections made from wood, animal skin, textiles, ceramics, beads, metals, and bones. The ethnographic collections are mostly constructed with organic-based materials such as plant and animal fibers.

Built into NMP's governance and care of collections, is access where 'all programs and activities of NMP'…are…'geared towards preventive conservation of the national collections without sacrificing public access' (Labrador and Tauro, 2019, p. 70). In providing access, the NMP is instrumental in keeping cultural communities and their customs alive through its acquisitions, exhibitions, and public programs and has a high regard for Indigenous knowledge holders. It also serves the public by being an educational institution disseminating knowledge through field and scientific research. Therefore, one of NMP's important duties is to sustain strong relationships with its primary stakeholders – the Filipino nation.

As such, much of the collection is on display. The NMFA includes 29 galleries compared to 3 collection stores, and similarly the NMA comprises of 14 galleries and 5 collection stores. In general worldwide, collecting institutions display less than 10% of items in science museums, 5% in ethnographic museums, 1% in biological and geological museums, and less than 20% in the fine arts galleries (Kreplak & Mairesse, 2021). Although the proportion of gallery to storage spaces cannot be correlated with the percentage of collections on display versus in storage, it could suggest NMP's greater emphasis on access and exhibition. For the NMP, inclusion, public access to collections and socialized knowledge is a priority and part of its museum act (Republic Act No. 11333, 2019). This is translated into practice with free entry into the museum, and internal doors are purposefully prized open to invite visitation in preference to the climate control offered by the double doors built into the historic building to enclose rooms. The large 'Spoliarium' painting by Juan Luna y Novicio (1857-1899) is an example, as visitors are greeted by the iconic painting immediately as they enter the NMFA. This has positive benefits for the public but equally challenges for the paintings environmental care and permanence in the tropics.

4.3 The museum climate: temperature and relative humidity and analysis of data collected

Figure 7 shows two psychometric plots for the 4th floor NMA building over one year from 30 March 2020 to 3 March 2021. On the left is the Rice Gallery which faces southwest and the Hibla Gallery towards the northwest. Both plots show sustained high levels of relative humidity and temperature, three quarters outside the HCC targets. This is greater for the Rice Gallery that faces more towards the south and experiences the higher building climatic loads from the sun and elevated daytime temperatures. Of note is the wet and dry season of the Hibla Gallery (see Figure 7 on the righe). Risk points are relevant to half of the dry season and all of the wet season when values are above the 70% biodeterioration threshold. As will be examined later, the intermittent operations of the AC units, caused condensation on the surface of the collections which are mostly organic. Similarly, the 3rd floor NMA plots follow the same trend with variations between the galleries facing northwest, the Bangsamoro and Lumad Gallery, and east facing, the Biyay Gallery. Assuming all the HVAC systems are performing well, it seems each gallery space holds a climate specific to its location in the building and floor level. Understanding what each gallery can achieve is a key step towards the zoning of climates for collection types and risk levels.

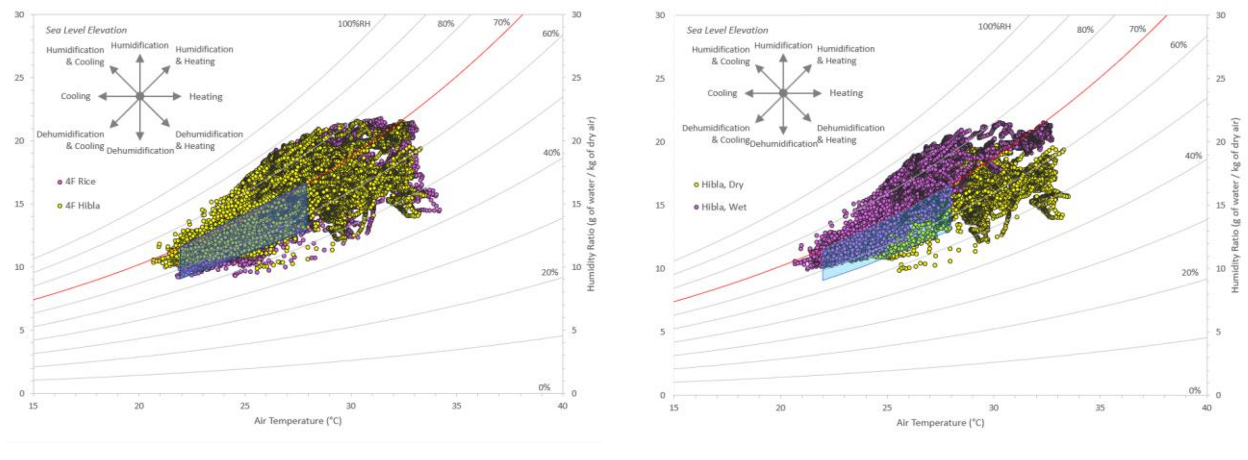

Figure 7. Psychometric plot of the 4th floor of the National Museum of Anthropology (NMA) Building from March 2020 to March 2021, air conditioning on in the day and off at night. The red line is the 70%RH threshold for biodeterioration. Left: 4th floor Rice Gallery facing Southwest compared to the 4th floor Hibla Gallery facing Northwest, and blue quadrant outlining the Heritage Collection Councils (HCC) 's targets for hot, humid climates: 22-28oC and 55-70%RH, Right: 4th floor Hibla Gallery, NMA building comparing the wet (purple) and dry (yellow) seasons and the blue quadrant outlining HCC's target.

While the psychometric plots from the NMFA's Gallery 2 as shown in Figure 8 on the left and Table 1, presents the intermittent use of HVAC and the wet and dry season over a 1-year period from 6 December 2017 to 23 February 2019. Effectively, the dry season corresponds with the HCC targets and the wet season does not, highlighting the 'at risk' period above 70%RH. This is when extra attention and the use of dehumidifiers is necessary. The monitoring of dehumidifiers, emptying of accumulated water and record keeping, was a task assigned to the security staff, which during the wet season was about one bucket plus every morning (Balarbar, 2023). Figure 8's two psychometric plots is also useful to compare intermittent use of HVAC in Gallery 2 on the left, with an internal location with no mechanical controls on the right. Located in a stairwell on the 4th floor, the plot on the right with no climate controls, corresponds very little with the HCC targets. The option of non-mechanical climate controls within the NMFA building is, therefore, not a real possibility. As a retrofitted historic building in the tropics, the NFMA has 'poor air control performance' with air exchanges through windows and doors, and this can amplify external climates rather than reduce extremes. The small daily variations in the tropics, means that overnight cooling is difficult.

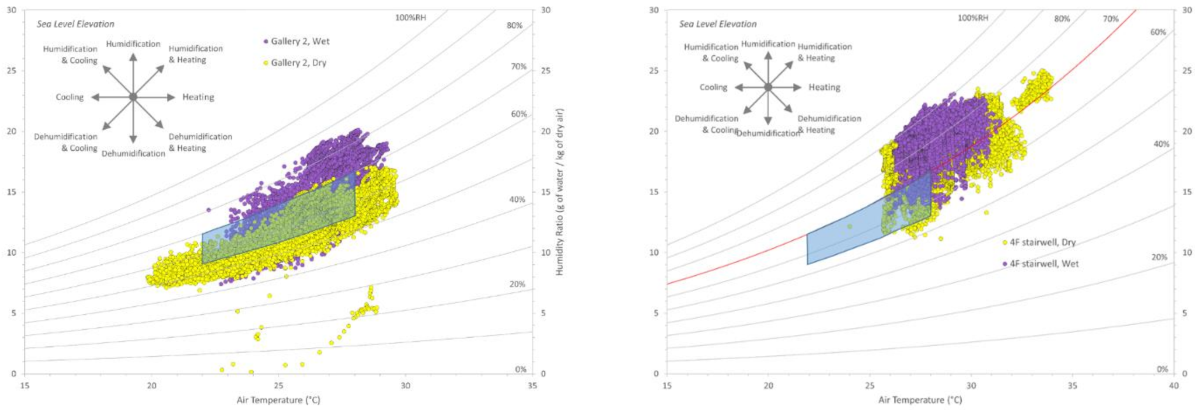

Figure 8. Psychometric plot of the National Museum of Fine Arts, coloured blue quadrants outlining the Heritage Collection Councils (HCC) 's targets for hot, humid climates: 22-28oC and 55-70%RH. The red line is the 70%RH threshold for biodeterioration. Left: 2nd floor Gallery 2 facing west from data obtained from 6 December 2017 to 23 February 2019, air conditioning on in the day and off at night with the wet season (purple) and dry season (yellow); compared to Right: the 4th floor stairwell, internal location without air conditioning from 10 April 2017 to 15 July 2018,

Like many collecting institutions worldwide, the pandemic has offered the opportunity to assess the performance of buildings without mechanical systems for collection care. Such was the case for NMP and Figure 9 from the 3rd floor of the NMA building shows the Biyay Gallery and how the temperature and %RH readings stabilized when the mechanical controls were not used from 30 March to 5 May 2020 and 4 September to 21 October 2021 (the same trend was found for the Bangsamoro, and Lumad Galleries on the 3rd floor). The maximum %RH levels dropped from between 80-90%RH to 70%RH to minimize mould risk, as did the dew point temperature and the %RH range to +/- 5%RH. Temperatures also stabilized and flatlined to above 30^{o}C. This is outside the environmental standards mentioned earlier and could result in thermal ageing up to 3-4 times faster compared to 20^{o}C, if for example, a work on paper, picture varnish or weighted silk (Tetrault & Dupont, 2019; Michalski, 2002). When mechanical climate controls are not in use, it is clear there are the competing impacts such as the reduction biological risks vs increased thermal ageing, to the benefits of energy savings vs access if galleries are cooled with HVAC.

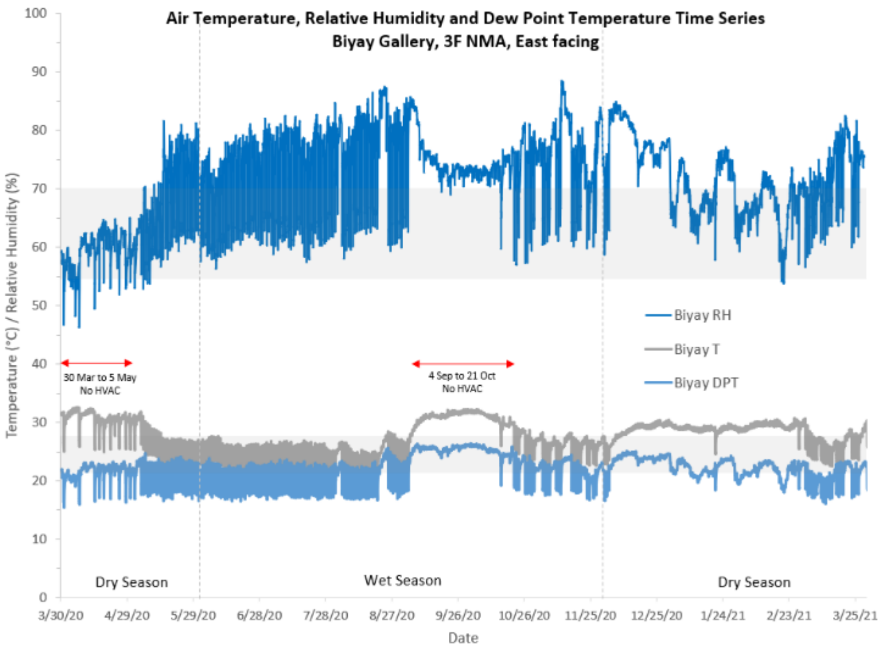

Figure 9. 3rd floor of the NMA building shows how the temperature and %RH readings stabilized when the mechanical controls were not used from 30 March to 5 May 2020 and 4 September to 21 October 2020 October as indicated by the red arrows. Readings from the Biyay Gallery on the 3rd floor of the National Museum of Anthropology. The grey band indicates the 70%RH threshold target for biodeterioration, and the lower blue plot is the dew point. Graph was generated using the Onset Hoboware Software for Data Loggers and Devices, Version 3.7.26, 2023.

To assess when the risk of mould may occur, Figure 10 shows a time series plot with data from the NMA building. It compares two locations, one within the GAMABA display case as an example of a microclimate to buffer the extremes, and one within the Rice Gallery, on a different floor but also a southwest facing gallery. The GAMABA display case buffered with silica gel, reduces the extremes in temperature and %RH compared to the Rice Gallery, but levels are above the 70%RH risk threshold for mould. The potential for mould would therefore be contained within the case and the limited air movement, contributes more risk. The demands of the wet season are also shown. In the initial months, the GAMABA display performs better than in the latter wet season, when humidity rises above the 70%RH threshold and the 24 hr range increases above 10 %RH. Here, either the silica gel is saturated and not performing, or the display case is not retaining its micro-climate.

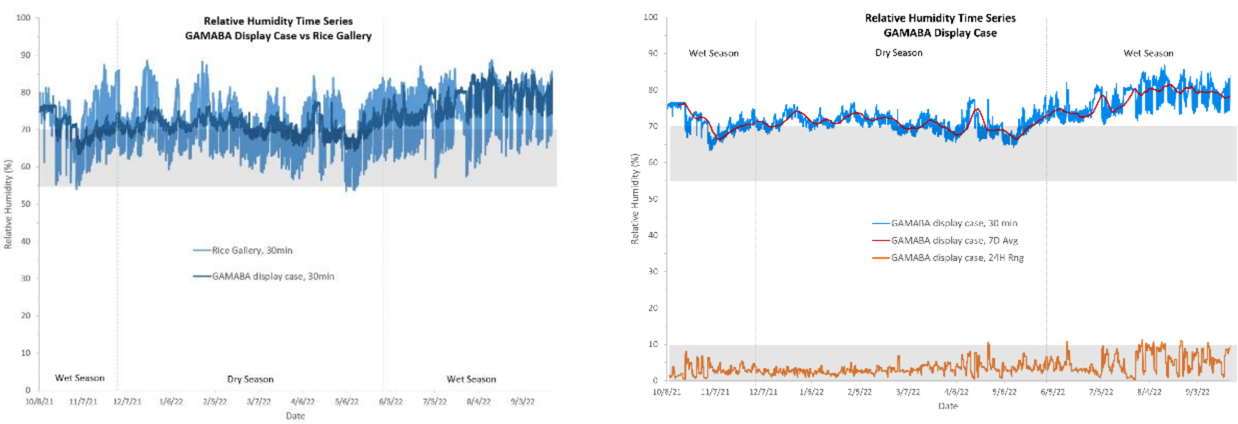

Figure 10. NMA Building showing the effects of a microclimate display buffered with silica tray drawers compared to an internal gallery space, both southwest facing galleries, time series plots, 8 October 2021 to 23 September 2022 over a wet to dry to wet season. Left: GAMABA display case on the 3rd floor, and the 4th floor Rice Gallery, time series 30 min moving range, Right: GAMABA display case with 3 time series plots at a 30 minute, 7 day average and 24 hour moving range.

4.4 The museum climate: temperature and relative humidity datalogging

Clearly the environmental plots imply mould growth with gallery climates recorded above the 70%RH threshold. During the wet season, the dew point temperatures were reached in display cases and open spaces. Examination of collections and change during this period, illustrated this relationship and micro-organisms were identified in the NMA building on ethnographic collections on open display, in storage areas and frequently inside glass cases. Figure 11 shows examples of ethnographic and archaeological collections with mould growth. The same applies to some of the inorganic collections under the care of the Archaeology Division, with mould occurring on earthenware and ivory which was unexpected (although partly organic) (C Valencia 2023, pers. comm., 23 June). NMP staff were also alerted to possible mould growth during the pandemic when security was only permitted on the NMP site, and they were tasked with environmental monitoring and collection assessments at 10am, 12pm, and 3pm. These records were useful to inform collection risks and compare to the datalogging readings and trends, but particularly it has built awareness beyond an individuals or divisions responsibilities.

Figure 11. Examples of ethnographic and archaeological collections with mould growth. (a) wooden spoon at the Rice Gallery open pedestal (b) nut at the Rice Gallery open pedestal (c) Butuan ivory seal, 10th –13th c. AD, placed inside a glass case at the Baybayin Gallery (d) Calatagan Ritual Pot 14th-15th c. AD placed inside a glass case at the Baybayin Gallery. Photographs by and produced with the permission of Dr. Marianne Ubalde, 11 October and 6 December 2022.

In effect, the occurrence of mould, accumulated dust, and dead insect finds, has prompted weekly maintenance of collection displays in galleries. Every Monday as a weekly activity, the Ethnology Division Curator Marites Tauro explains how time and effort is given to cleaning and maintenance of mould effected collections caused by climate (M Tauro 2023, pers. comm., 19 September). Cleaning and opening of display cases alters the %RH and disrupts the buffered moisture content within the cases when HVAC units are not in operation on Mondays and galleries are hot and humid. Figure 10 on the left shows the annual %RH data in the Rice Gallery external to the display case exhibiting the spoon and nut in Figure 11a and b, and the climates the collections are intermittently exposed to. The effects of large climate changes are also evidenced in Gallery 2 of the NMFA building. Panel paintings as composite collections, appear to be undergoing dimensional changes and cracks, and delaminated paint forms soon after treatment. Annually datalogging over the wet and dry season shows 43-73%RH and 20 -30°C, beyond the tolerable fluctuations of 20%RH and the increase risk of fracture (see left plot in Figure 8) (ASHRAE 2019).

Colin Pearson (1991) noted that mechanical systems are expensive and 'rarely compensate' if the operation does not complement the needs of the building fabric. For the NMP, there are clearly issues with the HVAC units and evidently only a small portion of the recorded climates correspond with the HCC (2002) hot, humid targets. However, as mentioned the option of non-mechanical climate control for the NMA buildings are difficult due to visitor expectations, and the retrofitting NMP's historic buildings. Figure 8 compared to Figure 1 illustrates this well. The temperatures recorded in the stairwell of the 4th floor are above the mean average external temperatures in Figure 1. This is due to the small daily fluctuations in the tropics making overnight cooling difficult. In effect, the building envelope has a higher 'risk of condensation and high moisture content' (Maekawa, Beltran & Henry, 2015).

5. CONCLUSION

In summary, key to this paper's analysis are the thresholds for collection care and the effects of climate on collections belonging to the National Museum of the Philippines, an institution situated in the tropics in an urban centre and undergoing significant organizational changes and growth. The hot, humid climate has its collection challenges as change is faster and the effects of ageing heightened, as does the steady rise in temperature and the threat of natural disasters. This has implications for the life expectancy of collections held in the tropics. The combination of sustained high temperatures and %RH levels above the 70% mould threshold, dry and wet season variations, along with the fluctuations brought about by the intermittent operations of HVAC units to reduce energy costs, has been a space to engage with the divisions concerned with collection care and facilities management. An analysis of climates without the operation of HVAC units during the pandemic and non-climate-controlled spaces, has enabled a deeper understanding of the building performance and poor building envelope as a retrofitted historical building. Further the reporting of energy costs along with an evaluation of the climate related risks in the building, could incentivise improvements and bring down costs.

Overall, the psychometric plots drawn from longitudinal datalogging from different galleries, do not fully align with Australia's HCC targets for hot, humid collections. The data does show the differences between galleries, where the HCC targets are met and zoning of more sensitive collections could be considered. The time series plots illustrate the dry to wet seasons and dew point temperatures in display and gallery spaces, highlighting the times of the year when the risk of biodeterioration is critical. Together they show that climate control for NMP collections is challenging, but also when attention and dedicated resources are needed to manage collections.

With NMP's recent growth and greater autonomy, principles of collection care and access, the climate challenges, and practicalities of energy consumption in the tropics, are being considered to create strategies for collection care in hot, humid climates. This paper highlights the complicated responsibilities for museums in challenge-led locations in the global south.

Author Contributions: Both authors, Calanno and Tse, conceptualised and drafted the original paper. Calanno and Tse recorded the climate readings and examined collections and their behaviour over the duration of the study. Calanno processed the datalogging files into psychometric and time series plots, and undertook interviews with NMP staff. Tse supervised Calanno's minor thesis on the topic. All authors have read and agreed to the published version of the manuscript.

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