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Indoor Climate Characterisation of the Quarantine Room of NTNU University Library

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***Abstract* – Archives, museums, and libraries can have quarantine rooms as storage areas in which incoming collections are temporarily housed. The purpose of the quarantine period is to control the object' state in case of appearance of signs suggesting ongoing chemical and biological alteration, before being placed in conservation or exhibition spaces. Inappropriate thermo-hygrometric conditions of such spaces could negatively affect the chemo-physical properties of organic materials commonly stored in archives, leading to possibly irreversible changes. This contribution deals with the characterisation of microclimate inside a quarantine room, located in Dora I (Trondheim, Norway) over a multi-year period to highlight conditions that may have led to a rise in insects' presence within the same area. The outcomes of an entomological and microclimate analysis within the room show that no significant variations were experienced in the indoor hygrothermal behaviour over the years, and the peak of insects catches happened in July and August 2022. Preventive measures are finally formulated to help in detecting the potentially infested objects and minimizing the possibility of biological proliferation on artifacts.**

I. INTRODUCTION

It is nowadays well-known that indoor climate conditions in spaces housing climate-vulnerable cultural collections (e.g., cellulose-based materials) can pose a risk in terms of biological, chemical, and mechanical degradation [1,2,3,4]. For this reason, in the preventive conservation, the monitoring of temperature and relative humidity is becoming a common practice within museums, churches, archives, and historical buildings, and it is recognized to be an effective task to assess the conservation risks induced by microclimate conditions. Quarantine rooms represent holding areas where incoming collections are temporarily isolated (e.g., from 2 weeks to 40 days) and inspected to check for signs of fungal and/or insect pests' infestation, as well as of ongoing and progressive chemical reactions taking place in the materials, before being stored in the permanent exhibition/storage space [5]. This step would need to be carried out in a monitored condition of temperature (T) and relative humidity (RH), suitable for the conservation of vulnerable objects that could eventually already be affected by biological or chemical degradation. The biodeterioration induced by insect pests, is a well-known issue in the field of heritage science, especially when dealing with cellulose-based artefacts [6,7]. In this context, Integrated Pest Assessment (IPM) [8] plays a key role in the prevention of pest infestations and in the reduction of pesticide application. IPM is usually accomplished by sealing the space against pests, keeping T and RH at specific values not favouring infestation, maintaining high hygienic standards, quarantining new and incoming objects, and monitoring pest infestations with traps [9]. As recommended by the standard EN 16790:2016, if any sign of active infestation/contamination is discovered, infested/contaminated objects should be treated. Other objects around those infested should have special attention too [10]. Based on this, all space housing heritage collections should have a designated quarantine area for incoming artifacts [11], however, this is not always possible due to the lack of dedicated spaces. In addition, no scientific publications have been focused on

this topic probably because these spaces are temporary storage areas. Being this type of space poorly explored, the main aim of this research is the characterization of the microclimate conditions within the quarantine room of Dora I (Trondheim, Norway) to analyse the temporal behaviour of indoor temperature and relative humidity by comparing them over the years.

II. MATERIALS AND METHODS

The quarantine room under study is located within the WWII U-boat facility of Dora I(Trondheim, Norway, Lat. 63.4°N Long. 10.4°E, 3 m a.s.l.), and it is currently used by four different archival institutions: the *NTNU* (Norwegian University of Science and Technology) *University Library*, the *Regional State Archives* (part of the National Archives Services of Norway), the *NTNU Department for documentation management,* and the *Trondheim City Archive*.

A. Incoming heritage collections

The quarantine room used by archival institutions houses several (mostly organic) materials, as being part of library collections. *Fig. 1*(*a, b, c, d*) shows some of the items preserved in the quarantine facility at the time of the survey (e.g., books, maps, archival documents, photographs differently aged and coming from different donors).

When the incoming collection consists of many volumes, the conservator personally inspects the objects before it is brought inside the quarantine zone. In this way, if the objects are infested with biodeteriogens (e.g., insects or mould), they are immediately placed in cold rooms at -28ºC for 2-3 weeks to favour a comatose to dead status and inhibit pests' growth. It is worth noticing that for many years no clearly visible infested objects entered the quarantine room.

The protocol followed by the staff of the archive for incoming items is that they are isolated in the quarantine room for a period of at least 2 weeks in order to be checked for eventually following pest infestation and/or ongoing chemical reactions taking place on the materials. Depending on the dimensions of incoming objects, they are usually held during the quarantine period in a box, inside which an entomological trap is also installed to control the object more strictly (*Fig. 1c*). Donations consisting of large quantities of objects in some cases are not monitored through insect traps, but by putting a line of double-sided adhesive tape on the floor surrounding the material.

Fig. 1. Examples of materials stored within the quarantine room at the time of the survey; a) administrative paper sheets; b) photographs; c-d) photos album with cardboard covers.

B. Monitoring campaigns

The quarantine room is divided into different zones that are used by several archival institutions. *Fig. 2* shows a drawing of the subdivision and location of openings within the space. The only external wall is the seafront wall which is characterized by the presence of two automatic metal doors that should never be open simultaneously. The space between the two doors is usually occupied by vehicles transporting incoming collections to be stored within the quarantine space and it can in some cases be used to collect cardboard materials/boxes and pallets waiting for disposal.

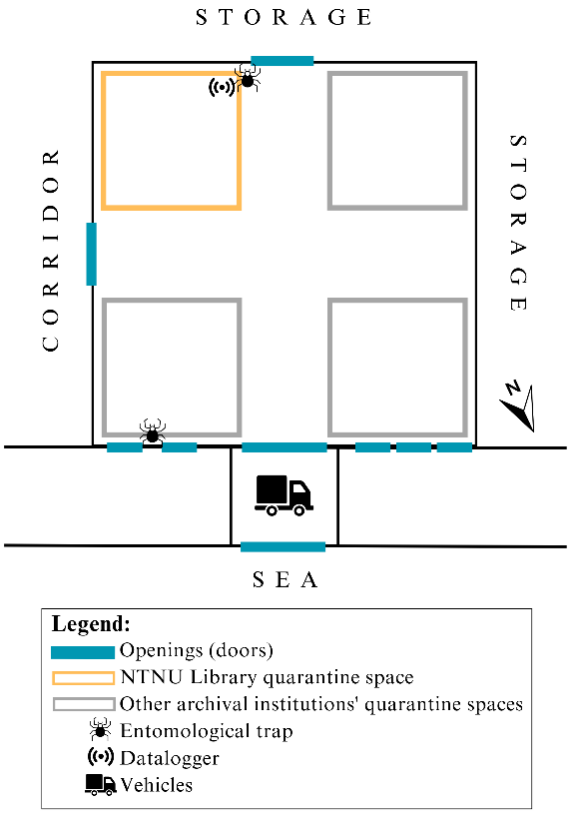

Fig. 2. Plans of the quarantine room with the position of the monitoring system device (for temperature and relative humidity) and entomological traps.

An indoor monitoring campaign has been carrying out since 2019 to study the hygrothermal behaviour of the quarantine room through the analysis of temperature and relative humidity data collected by the sensors (TinyTag-4500 manufactured by Gemini Data Loggers) placed on a shelf at a height of 1.8m above floor. The technical features of T and RH sensors (reported in Table 1) are in accordance with the European Standards [12,13] and the time interval between consecutive observations was set to 3 hours. Moreover, monitoring of pest infestations in the same room was performed thanks to the use of two PELtrap Insect Monitor Window Traps located next to the emergency exit and in the proximity of one of the walls (as shown in Fig. 2). The non-poisonous insect glue traps were used to capture, monitor, and observe insects using lures (i.e., a powerful banana-scented attractant that works on most crawling and flying insects). The installation and inspection of the traps was manual and was carried out at the beginning of every month. Both microclimate and pests' infestation monitoring campaigns started in 2019 and are still ongoing. Data collected through the above-mentioned campaigns over the 2019-2022 period are used in this study. The analysis was conducted on each of the 4 years: I year (period between 01/03/2019 and 31/12/2019), II year (period between 01/01/2020 and 31/12/2020), III year (period between 01/01/2021 and 31/12/2021) and IV year (period between 01/01/2022 and 31/12/2022).

Table 1. Metrological features of TinyTag TGU-4500.

Variable	Sensor type	Uncertainty	Response time
T	10K NTC Thermistor	±0.6 °C	20 mins to 90% FSD in moving air
RH	Capacitive	±3.0%	10 seconds to 90% FSD

C. Indoor climate characterization and pest's infestation assessment

A preliminary evaluation based on visual inspection of the collected insect pests was performed by counting them and pooling the number of specimens found for each year, to highlight the months characterized by a greater frequency of catches.

Indoor climate was then analysed according to the following steps. The overall data quality was assessed by using the Completeness Index (CoI) and the Continuity Index (CI). Both indices range between the unity (i.e., no missing data and/or no outliers due to instrumental errors or anomalous parameter's behaviour) and zero (i.e., several missing data and/or maximum number of intervals) [14].

Exploratory data analysis included the Box-and-whisker plots. These plots provide a synthetic visualization of data without making any assumption on data distribution.

III. RESULTS AND DISCUSSION

The pest's infestation monitoring conducted through the two *PELtrap Insect Monitor Window Traps* within the quarantine room of Dora I resulted in the overall record of 18 insects (mainly belonging to the order of Coleoptera and Diptera) over the whole period under study. Entomological recognition was performed by means of photographic documentation; however poor resolution did not always allow to recognize the specimens at the genus level. Years I and II are characterised by many missing data especially due to the closing of spaces because of pandemic conditions. The year III provided empty traps for most of the time except for the fall-winter period (September, October, November and December) when 4 specimens were caught, one belonging to the order of Coleoptera (Suborder: *Polyphaga*, Genus: *Anobium*) and 3 belonging to the order of Diptera (Suborder: *Nematocera*). The IV and last monitored year appeared to be the one with the highest frequency of catches especially in summer (July and August) when both

Diptera (6 specimens) and Coleoptera (3 specimens) orders were found; but also in fall (September, October and November) with a minor number of catches (5 specimens) with respect to the summer period, again mainly belonging to the order of Diptera (Suborder: *Nematocera*).

The first step of the analysis on T and RH data series showed that both the T and RH series were characterized by CoI and CI close to the unity (i.e., to be of high quality for all the considered years) and hence suitable for exploratory data analysis.

Fig. 3 shows the Box-and-whisker plots for the indoor temperature (T). The line inside the box is the median value, with the 25th and 75th percentiles (lower and upper sides of the box), respectively. The whiskers show minimum and maximum values except the outliers which are drawn as circles (beyond 3 times IQR *interquartile range* – difference between 25th and 75th percentiles) [15]. Outliers occurred especially from the end of July to the beginning of September for years I and III probably due to the external hotter conditions which have characterized those periods. It can be noticed that the box plots of indoor T overlap since there is no significant difference among data during the four monitored years. The internal temperature is in fact always between 16.2°C and 18.6°C thanks to climate control system that is active throughout the year.

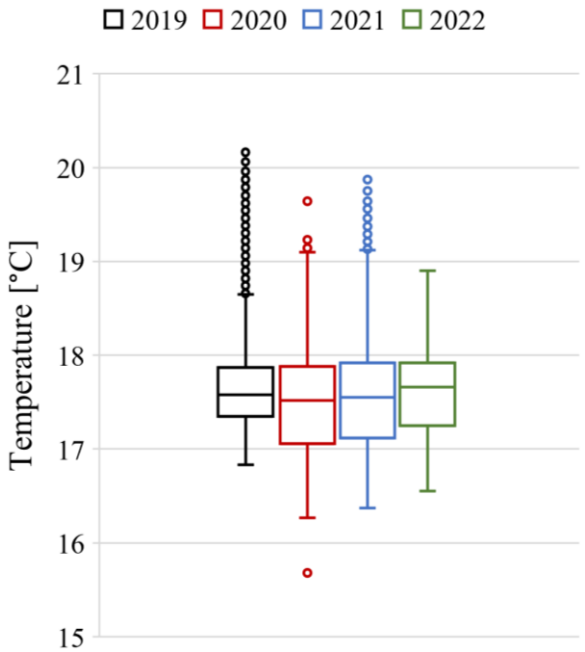

Fig. 3. Box-and-whisker plots of indoor T for each year. The line inside the box is the median value, with the 25th and 75th percentiles as lower and upper sides of the box, respectively. The lowest and the highest value of the data set are plotted as whiskers when they are not outliers, indicated as the circle.

Indoor relative humidity (RH) values reported in *Fig. 4*, again showed different variability depending on the years: from 17.1% to 86.6% for year I; from 18.3% to 79.4% for year II; from 13.2% to 78.1% for year III and from 13.2% to 87.1% for year IV. No outliers were identified for RH and its evident variability during the year allows to deduce that the climate control system is designed for maintaining a consistent temperature but not for controlling relative humidity within the quarantine space.

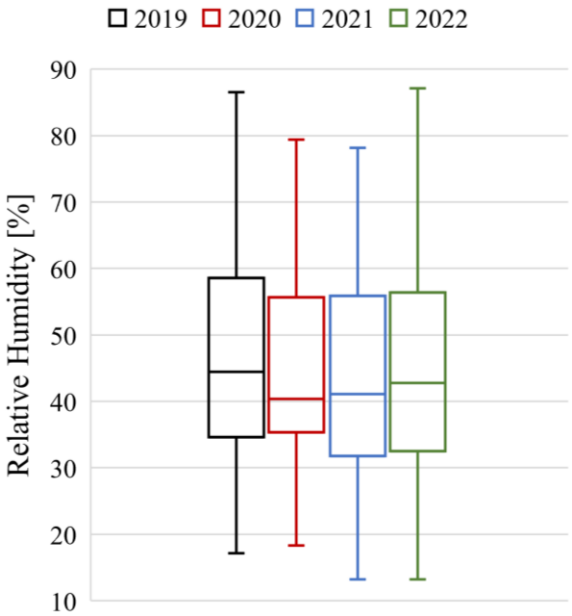

Fig. 4. Box-and-whisker plots of indoor RH for each year.

In general, insects need mild (i.e., T between 15°C and 30°C) and moist air (i.e., RH between 50% and saturation) to proliferate; on the contrary when T and/or RH are lower some insects enter a comatose status for cold and/or dehydration. Since the temperature values within the quarantine room are always between 16.2°C and 18.6°C (without considering outliers), these could represent favourable life-cycle conditions for many insects, especially when combined to equally suitable relative humidity ranges (that are however not always met during the whole year). High humidity fluctuations, in fact, pose a moderately high risk for paper-based, textile and wooden materials as they favour eggs, larvae, and mature insects' proliferation [16, 17]. For this reason, hints for keeping collections safe from pests include maintaining the RH low. If collections must be stored in damp environments (e.g., basements) and/or micro-environments such as storage cabinets, these spaces should be passively controlled with a desiccant such as conditioned silica gel [18].

In the present investigation, insect pest's presence found within the traps in the autumn 2021 and 2022 may

be addressed to simultaneous indoor temperature and relative humidity conditions more suitable for pests' metabolism and proliferation. However, since no significant variations over years were experienced in the indoor hygrothermal behaviour; the peak of insects catches in July and August 2022 could be eventually justified by the entry of an infested object or boxes from the outside that could have caused a higher presence of insect pests.

IV. CONCLUSIONS

Based on the microclimate and entomological preliminary analysis carried out in this work, the following considerations are proposed:

- Regularly inspect to check for visual traces and/or residues of insects together with adequate cleaning regimes to remove food and dust debris from the space, always ensuring the closure of at least one of the two doors separating the quarantine room from the outside.
- Continue to conduct monitoring with entomological traps, in order to detect a possible incipit of infestation and/or to check the trend of the infestations in place.
- Maintain, when possible, temperature and relative humidity conditions in the range of values not suitable for entomological development.

Further research on this case-study will be addressed to carry out a comprehensive biological risk assessment for the vulnerable material temporarily preserved within the quarantine area. To this aim, future photographic documentation will be implemented to better perform the recognition of the specimens caught at the species level. Insect pests' infestation threatening the heritage collections should be evaluated by means of specific indices which consider temperature and relative humidity thresholds in order to identify other suggestions capable of improving the "safe" conditions inside the quarantine room.

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