Implementation of disaster risk management for the "Zoothèque" at the National Museum of Natural History, Paris, France

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1) Introduction

The institution

The National Museum of Natural History (MNHN) is a French institution for research and the dissemination of scientific culture. It is one of the first world establishments of this type, inheriting the Royal Garden of medicinal plants founded in 1626. The MNHN has five missions: the conservation of scientific collections, the dissemination of scientific culture in the specialties of the institution, research, teaching and training, and scientific expertise. In the centre of Paris, it encompasses eight galleries, one library, a zoo, gardens and greenhouses spread over 25.7 ha along the Seine River (Fig.1). The museum's collections of specimens are a heritage for humanity, as they are essential for understanding biodiversity. The museum houses around 68 million specimens that are available to all researchers. To store some of the zoological collections that are not exhibited, a new building was inaugurated in 1986 (Fig.2). This storage facility, called the "Zoothèque", is the subject of this disaster risk management (DRM) study, which aims to implement the best preservation of the value of this heritage asset using the available resources.

Context: core, attributes and values

The Zoothèque is an underground storage facility that is home to thousands of the museum's birds, mammals, reptiles, amphibians and fishes. Located on the premises of the MNHN, in Paris (48.842323, 2.357097), it houses 8 million specimens, or 20,000 m^3 of various artefacts, stored on 40 km of Compactus shelves over three levels (Fig.3, 4). The items consist of stuffed specimens (dry), a wet collection (specimens in alcohol or formaldehyde) and a collection of "type" references for scientists (Fig.5, 6). These collections are at the basis of the classificatory analysis that rationalizes nature and man, and leads to phylogeny, that is to say, the evolutionary history of life. They also serve as the subject of research in the areas of the natural sciences and reference for the expertise of the inventory of the diversity. Besides the scientific value for the academic community, this collection has a historical value due its provenance, as well as an educational value for the public at large.

2) Risk Assessment

Threats and vulnerability

The Zoothèque is in a flood zone, 200 meters from the river. In case of flood, basements of the neighbourhood will be flooded first. The water will infiltrate either from the top of the Zoothèque, or by rising in the drains, and will then stagnate in the building. The collections that are stored there are particularly vulnerable. The specimens are made of organic materials (such as feathers and fur), which will be seriously damaged by the water; moreover, they will release the toxic products (such as salts of mercury and arsenic) that were used as pesticides until the early 20^{th} century when stuffing specimens. If flooding occurs, the jars filled with specimens stored in alcohol and formaldehyde will float, lose their tags, shock to each other, break and lead to the loss

of specimens and the release of formaldehyde, a carcinogenic substance. Another problem that has already been identified for a neighbouring building of the museum is the collapse following a subsidence of the land. Thanks to the underground situation, the storing benefits of a great thermal inertia but this has the disadvantage of leading to high humidity due to water infiltration. As a result, the collections have been regularly subject to fungal contaminations. The problem is amplified by the presence of Compactus shelves that create containment and facilitates cross-contamination carried by excess dust. Air conditioning maintains a stable temperature but does not control the humidity. Finally, it should be noted that there is a substantial reserve of alcohol (600 liters) used by the scientists that could amplify or promote a fire. It should also be noted that there are no permanent staff on the site, and there is a lack of awareness among the various actors, lack of an emergency plan, and lack of training for emergency interventions with the staff of the institution.

Tangible and intangible impact

Such events would lead to the damage or even the loss of unique or historical specimens, resulting in an impoverishment of the collections. Scientists would lose not only a source of reference for their studies on the living, the study of biodiversity, and evolution, but the impoverishment of collections could lead to a decrease in the number of visitors and the associated revenues for the institution.

Risk analysis and evaluation

By representing the hazards according to their probability and the impact on the collections, we can establish a matrix that will make it possible to prioritize the actions (Fig. 1). The risk of collapse is unlikely as the building is underground and build following recent standards. The same is true for mechanical damage: the artefacts are barely handled and stored stably on the shelves. These risks, with a magnitude of less than 5, are currently accepted. Mould and fire are significant risks (5 to 8) that should be reduced. The temperature is controlled and maintained at a constant temperature of 16° C to ensure optimum conservation of the specimens; however, the constant excessive humidity level induces mould infestations. The museum has already begun procedures to clean the atmosphere of this building to reduce moisture and biocontaminant load. The presence of a significant quantity of alcohol is subject to the control of authority external to the establishment. The building is equipped with a fire detection system. Fire extinguishers are present on the premises and a security team is permanently present nearby. The hazard that induces a high magnitude of risk (greater than 9), and that should be urgently reduced, is flooding.

Past history hazard and worst scenario

A flood of the Seine occurred in 1910, and various parts of the MNHN were affected. In 2016, the Seine reached a critical level without leading to a flood of the museum. However, Paris and its region expect a 100-year flood of the Seine. Indeed, even though retention basins have been built around the city, their efficiency decreases with the increased urbanization of Paris and its region. The worst-case scenario may then be considered: when the level of the river reaches a critical point (predefined by the civil security), the alert will be given and museums in Paris will start to apply emergency measures. In less than 24 hours, the garden will be flooded. The museum staff will start to protect the sensitive objects and materials in the other museum galleries or move them to the upper floors. Specialized staff will transfer animals from the zoo. In the meantime, the water will penetrate the lower levels and flood the Zoothèque. It will be difficult if not impossible for safety reasons (chemicals, low air quality, lighting) to intervene in the storage facility. Furthermore, the ability to open the Compactus shelves might be compromised. If it is not possible to avoid a river flood, the impact should be reduced by preventive measures.

3) Risk Prevention and Mitigation

Evaluation of the disaster management system

The building is only 20 years old and it adheres to the recent safety standards for people. There is a basic maintenance and monitoring of the building. The building and its contents have been declared to the local safety authority because a significant quantity of flammable liquid (ethanol) is stored on the premises. There are regular inspections, in particular for smoke detectors, which are connected to the security office. A team of firefighters is permanently at the MNHN and ready to act if there is an alert. However, there are no permanent staff within the building, no flooding alert system, no evacuation plan for the collection, no first aid kit and no emergency power supply. In addition, these public collections are not insured.

Disaster risk mitigation plan

- **Avoiding:** The best option would be to move the whole collection to a safer location. The reallocation of this storage for another collection less water-sensitive (minerals, fossils, etc.) make sense; however, this seem difficult to achieve in the short term for financial reasons. Cheaper options would be to focus only on the most sensitive or most valuable specimens (the “type” references) that could be transferred to a safer place or at least to higher levels in the storage. This would mean rearranging the storage that has been made following a rational scientific organization.

- **Blocking:** In case of a flood, it will be important to buy time to keep the water out as long as possible. The installation of a pump with a power generator will help to remove some water at the early stage of the flooding.

- **Detecting:** A water detection system connected to the security office should be installed.

- **Reducing:** In order to reduce the impact of a flood, it is necessary to list the most valuable specimens to be evacuated in order of priority. This should be posted on the door of each room and on the Compactus shelves to be able to find them in an emergency situation. A mapping system to locate these artefacts has to be established and kept at both the security office and the building itself. Regarding the jars that store specimens in liquid, it would be worth studying the possibility of using plastic waterproof bags or containers as well as techniques to keep them stable and protected on their shelves during a flood.

- **Building on the 2016 alert:** For the entire site, the priority is to increase competences and staff involvement. This could be achieved by first recruiting a DRM coordinator and developing an emergency plan, an emergency response team and a reverse-planning scenario based on the lapse of time before the building floods when the river reaches a critical level. It is necessary to contact the firefighters for access and safety in the building before and during a flood, and to discuss with them and the civil protection about safety issues (e.g. toxic chemicals) in case of a flood. Among the stakeholders, residents, volunteers and museum supporters could be trained and listed for first aid in case the need arises.

- **Retrofitting:** Keeping the water out of the building or out of the storage rooms looks difficult to achieve considering the underground location of the building, but it is worth estimating the range of techniques that could make such a space (building or room)

waterproof for a period of time by delaying water infiltration through drains and access points.

4) Emergency Preparedness: Response and First Aid

In order to prepare responses when facing a disaster, all information about the collection (the most valuable items, a priority list) will be stored in a safe place. A list of volunteers (a rescue team) and an alerting system need to be established and stay updated through regular contact. An evacuation procedure has to be set and tested through drills. Shelters for the storage of artefacts in good condition and another for those damaged after a disaster have to be located. Specialized conservators have to be identified.

Response

In case of an alert, when the river reaches a critical level, the MNHN site will be closed to the public. This information will be spread through proper channels of communication to alert police, firefighters, the rescue team and the public. The president of the museum will launch the rescue and start to evacuate the collection in order of priority.

When the water floods the building, for safety reasons, there will be no access to the Zoothèque but the collection recovery will be prepared by contacting/organizing the rescue team, assessing the shelter and checking the supplies.

Recovery

After the flood, the firefighters will remove the water from the building with an efficient pumping system. As soon as the building is secured, the trained staff will assess the damage, the losses and the needs. The flooded collection will then be evacuated for air drying in a ventilated place (shelter). Its evaluation for conservation measures will be conducted using appropriate methods. Priority for conservation treatment will be established and a campaign for funding launched through media channels. The empty building will then dried by blowing warm dry air in it.

5) Conclusion

As a general conclusion, and for the first steps in order to improve the DRM in the short term, it would be advisable to recruit a coordinator for this activity with the task of establishing an evacuation plan and team, in order to identify the more valuable items and the strategy for saving them (and gathering this data in a safe but accessible place). This includes locating and flagging the most valuable artefacts, identifying shelters, and so on. In the medium term, an emergency team will be constituted and trained together with the museum staff to coordinate emergency procedures and to train other staff and volunteers. This will include evacuation drills and procedures for salvage. In the long term (5–10 years), it is expected that the collection will be moved to a safer place if it is impossible to make the storage waterproof. A study should be devoted to the methods of drying stuffed specimens after a flood. It would be advisable to increase the awareness of the museum staff and the public at large through a conference on climate change and its impact on cultural heritage.

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Fig.1: Administrative bundaries and core zone of the National Museum of Natural History (Paris, France). © *MNHN*

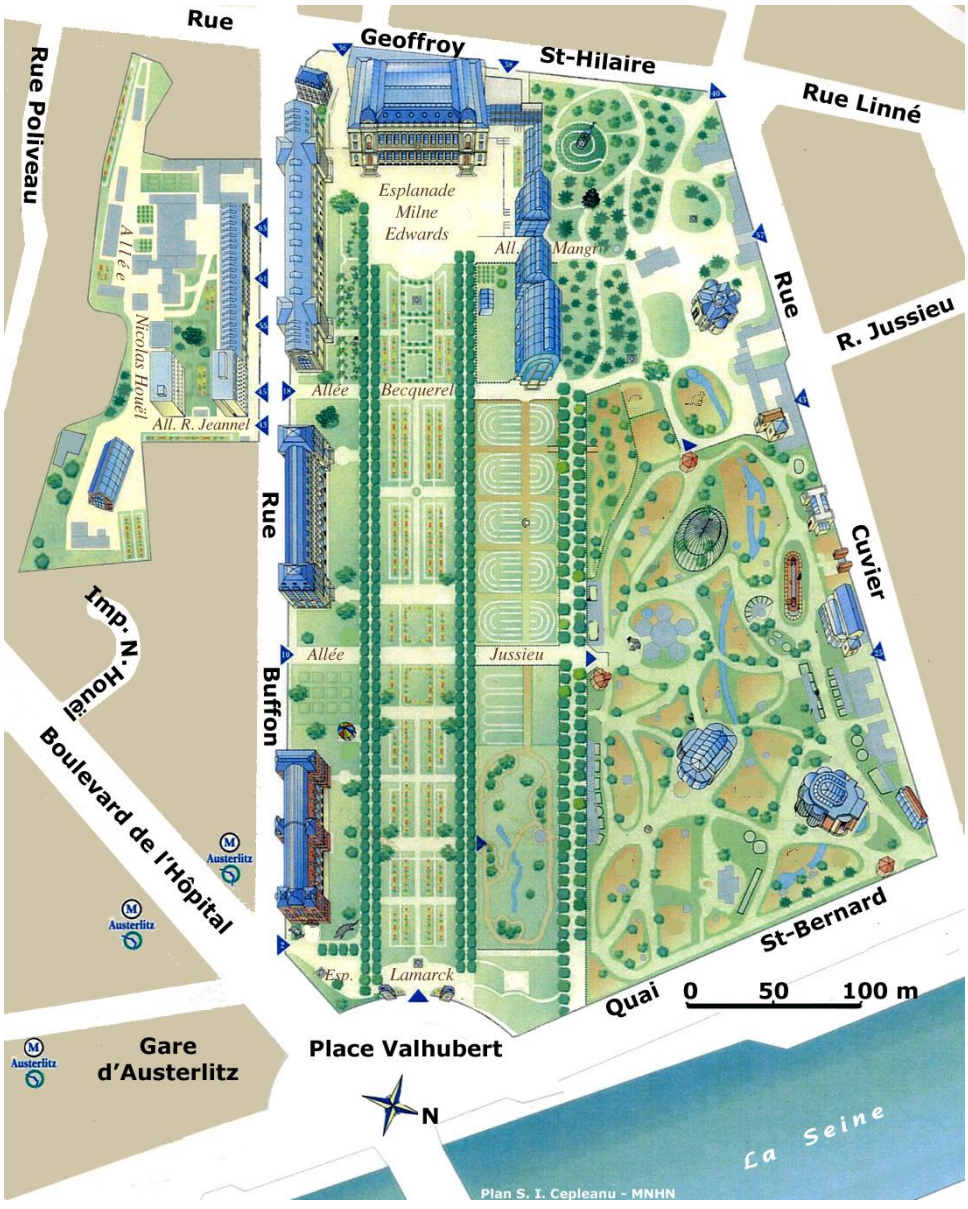

Fig.2: Construction of the zoothèque in 1981. © *MNHN* - Bernard Faye

Fig.3: Map of level (-1) of the zoothèque. © *MNHN*

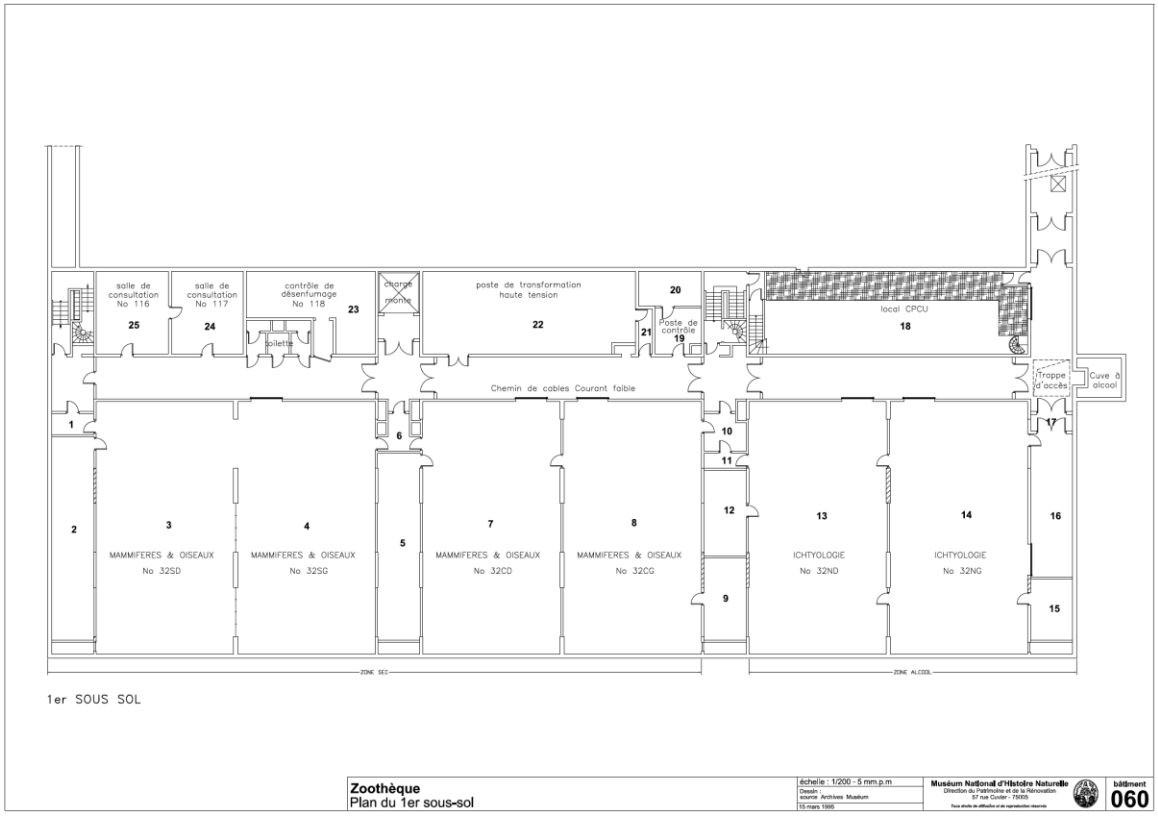

Fig.4: View of mobile shelving with stuff specimens. © *MNHN* - Bernard *Faye*

Fig.5: View of mobile shelving with stuff specimens. © *MNHN* - Bernard *Faye*

Fig.6: View of mobile shelving with fluid preserved specimens. © *MNHN* - Bernard *Faye*

Fig.7: Risk matrix and magnitude of risks

Likelyhood

Almost certain (4)	4	8	12	16
Likely (3)	3	**DUST/MOULDS** 6	9	**FLOOD** 12
Possible (2)	2	**PHYSICAL FORCES** 4	6	**FIRE** 8
Unlikely (1)	1	2	**CAVING** 3	4
	Moderate (1)	Minor (2)	Major (3)	Severe (4)

Impact