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Museums, Nature, and Society: The Use of Natural History Collections for Furthering Public Well-being, Inclusion, and Participation

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Abstract Natural history museums attract millions of visitors every year worldwide. Their collections, often inherited from centuries past, were gathered for scientific as well as educational purposes – and in many cases are still used for just that. However, since at least the 1950s, natural history collections have been perceived as a burden on museums and academic institutions, of little use other than exhibition in dusty cabinets, occupying space that could be used for more spectacular means of attracting the public. Yet natural history collections, even older collections, do have other uses, many of which have far-reaching consequences in terms of societal well-being, inclusion, and participation, which are often unrecognized in the collective mind of public and stakeholders alike. The aim of this paper is to review the available literature and discuss concrete examples where the use of natural history collections has resulted in benefits for society as a whole or within a single community. Natural history collections are repositories of reference material, allow earlier findings to be reproduced, and new technology constantly reveals new information no one suspected they could carry. New contributions of natural history collections are now more important to society than the original reason for going out and collecting specimens. They provide evidence of long-term historical trends, allowing researchers to make predictions into the future.

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Aline Donini is the owner and creator of Actias, a company providing consulting services to museums and the private sector. Aline has worked with natural history collections since graduating in biology, museology, and history of science. She has wide experience in preventive conservation, cataloguing and collections care, with a specialization in conservation of entomological collections. She also has experience in creating outreach workshops for schoolchildren and adults, having worked closely with several natural history museums in France and Switzerland. Aline can be contacted at: donini.aline@gmail.com.

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Introduction

Natural history museums attract millions of visitors every year worldwide (Jenkins, Lisk, and Broadley 2013). Their collections, often inherited from centuries past, were gathered for scientific as well as educational purposes—and in many cases are still used for just that (Johnson 2015). Since at least the 1950s, natural history collections (NHC) have been regarded as less important (Rader and Cain 2008), with few new collections being assembled and old ones perceived as a burden on museums and academic institutions, of little use other than exhibition in dusty cabinets, occupying space that could be used for more spectacular means of attracting the public. Nevertheless, NHC—even older ones—do have other uses, many of which have far-reaching consequences in terms of societal well-being, inclusion and participation, which are less known and seldom recognized in the collective mind of public and stakeholders alike.

NHC, in the words of Kress (2014), "provide windows into the past, inform about the present, and help predict the future of natural habitats and human-altered environments." They have been used to discover new species (Bebber et al. 2010), to investigate shifts in species distribution in response to climatic change (Lyons and Willig 2002; Peterson 2003; Moritz et al. 2008; Peterson and Martínez-Meyer 2008), phenological responses to climatic change (Nufio et al. 2010) or global environmental change (Lang et al. 2019), to study biological conservation (Pawar et al. 2007), land management (Ochoa-Ochoa et al. 2009), pollination (Biesmeijer 2006), invasive species (Giovanelli, Haddad, and Alexandrino 2008; Rödder and Lötters 2009), spread of pathogenic organisms (Moffett et al. 2009; Soto-Azat et al. 2010), and forecasting future changes (Graham et al. 2004). The wealth of data accumulated in NHC are used for statistical and model-based investigations in several fields (Lane 1996; Shaffer, Fisher, and Davidson 1998; Lister 2011; Lavoie 2013; DiEuliis et al. 2016; Willis et al. 2017; Rouhan et al. 2017).

Hill and collaborators (2012) cite many examples of ways in which NHC are used. Heberling and Isaac (2017) offer a comprehensive list of published papers of new uses for old herbaria. Funk (2003a) pools together 32 different uses of herbaria, later expanded to 72 (Funk 2003b), from basic research, education and outreach to money-making ventures. Carine and collaborators (2018) actually analyze the effective use of herbaria. With new technologies continuing to emerge, such as stable isotope analyses, massive parallel sequencing, or computed tomography, the importance of NHC and the variety of ways we can use them are continually growing (Bi et al. 2013; Rocha et al. 2014).

Many, if not all, of the uses of NHC have an impact on societal issues that afflict the contemporary world. These do not only affect global issues such as biodiversity loss, climate change, and environmental degradation, but also local issues that affect people and communities directly. The aim of this paper is to review the available literature and discuss concrete examples where the use of NHC has resulted in benefits for society as a whole or within a single community. Rather than reviewing more traditional fields of NHC activity (taxonomy, species description, or ecology), important though they are, we shall focus on seven areas where the use of NHC is perhaps less evident: public health and disease, trade and food security, crime and public safety, local communities and their identity, inclusion and participation, inspiration for art and engineering, and unanticipated uses.

Public Health and Disease

Healing the sick is not the first activity associated with NHC. However, research into public health, epidemiology, and cures for certain diseases (including vaccine development) very often depend on properly curated NHC (Suarez and Tsutsui 2004; DiEuliis et al. 2016). Molecular methods have allowed researchers to isolate DNA and other molecules from skin and bone samples from previously collected specimens (Bradley et al. 2014). Analysis of specimens in old NHC and repeat collecting of new specimens were used to identify the presence and transmission of Lyme disease (Persing et al. 1990), hantavirus (Sheldon and Dittmann 1997) or West Nile virus (Fonseca et al. 2001).

A textbook example is the use of NHC of birds from the Smithsonian Institution to compare preserved samples of influenza virus with human tissue samples from the flu pandemic of 1918 (Taubenberger et al. 1997; Taubenberger 2006; Fanning et al. 2002). If not for this NHC, researchers could not have concluded that the disease was not a type of avian influenza transmitted from bird to human, as had been previously thought, but a viral strain that routinely infected pigs and humans. Uncovering the true vectors of the pandemic has helped guide the development of containment policy. By tracking the virus's evolutionary history, using NHC specimens among other studies, vaccine development was improved (NSTC Working Group 2009). Mosquito collections have also been vital for understanding the dynamics of mosquito-borne pathogens and vectors of rapidly emerging and potentially fatal diseases such as West Nile virus (Lanciotti et al. 1999; Anderson et al. 2001). Pioneering work in parasite control (including malarial mosquitos) at the South African Institute of Medical Research has depended on NHC to guarantee not just taxonomic accuracy but breakthroughs in control (Coetzee 1999).

New viruses (arenaviruses, hantaviruses, and a tick-borne encephalitis) have been described from the analysis of blood and tissue samples obtained from NHC specimens (Milazzo et al. 2008, 2012; Cajimat et al. 2012, 2013; Inizán et al. 2010; Briggs et al. 2011). Finding certain viruses in NHC specimens is perhaps unexpected, and could not be done without proper curation of voucher specimens in NHC (Bradley et al. 2014). The Ebola virus was found in bats, both living and from NHC, which is vital information in the prevention of future outbreaks (Kemp 2015; DiEuliis et al. 2016). In 2012, researchers extracted viral DNA from 120-year-old koala skins and compared it with DNA found in skins from the 1980s to study the evolution of a retrovirus (Ávila-Arcos et al. 2013; Kemp 2015). Materials extracted from ancient bones are routinely used to study the evolution of viruses, informing the development of models that can predict the spread of modern diseases (Sholts, Bell, and Rick 2016; NSTC Working Group 2009).

NHC also play a central role in identifying pharmaceutical products. Screening of specimens in the collections of the Royal Botanic Gardens, Kew, England, revealed a new drug with potential HIV application (Boyd et al. 1994). Old labels on plant specimens can reveal medicinal properties which were lost in time; a survey of the Harvard herbarium revealed that many labels contain information about the medicinal use of plants by indigenous peoples (S. Li and Zhang 2014).

Environmental health officers use NHC collections to identify organic remains found in processed food which should not be there, from slugs in milk to bones from a suspect take-

away (NatSCA 2005). Biological collections also provide rapid identification for patients who have been bitten by animals thought to be venomous or who have eaten plants or fungi suspected of being poisonous (NatSCA 2005). The collections are also used to quickly identify pest infestation, either by direct reference or through the training of professionals based on them (NatSCA 2005). While each collection can have immediate and long-term uses, both for specific and more general uses, NHC at-large contribute to an incredible wealth of knowledge and possibilities for study and application.

Trade and Food Security

NHC are continually used to solve problems in agriculture and food production. They can assist breeding programs of new varieties: seeds of a new species of wild tomato in NHC led to a new cultivated hybrid estimated to be worth an extra $8 million USD per year (NatSCA 2005). Wild relatives of crop plants such as wheat, rice, and potatoes possess valuable genetic characters that give resistance to diseases, pests, or environmental stresses (NatSCA 2005). Citrus bacterial canker, for example, is a devastating bacterial disease of citrus trees and it is critical to understand its spread in order to develop appropriate methods for control or prevention. Scientists found the citrus canker bacteria on NHC herbarium specimens, allowing them to unravel the history of the disease and pin down its source. Neither the presence of the bacteria nor the existence of DNA, much less ways to analyze it, were envisioned when the leaf samples were collected (W. Li et al. 2007).

An example of the use of NHC in trade and food quality with a direct economic value was the claim that a shipment of wheat arriving in Algeria from the USA contained spores of the destructive Karnal bunt. The spores were compared with reference fungi in NHC and identified as an innocuous cousin of Karnal bunt, saving an annual US export market to Algeria worth $70 million USD (NSTC Working Group 2009).

NHC are of paramount use in tracking the progression of a pest, pathogen, or vector. In one case, researchers used NHC specimens to reconstruct the invasion history of one of the world's most damaging agricultural pests, the Mediterranean fruit fly (*Ceratitis capitata*) and advise measures for effective control strategies for this damaging and costly pest (Suarez and Tsutsui 2004). Experts have developed a system that allows port inspectors to rapidly and reliably identify fruit flies in the shipments they inspect (Davies, Villablanca, and Roderick 1999). NHC are indeed of outstanding value in the early and accurate identification of often quite indistinguishable pest species, they provide data to inform on their life cycles, larval growth patterns, mimicry, polymorphism, and migration. For example, NHC have been used to locate locust outbreak sites and track traditional migratory patterns (NatSCA 2005). Again, these instances all illustrate the importance of individualized data improvement, and together, contribute to a larger and contemporary understanding of trade and food security.

Crime and Public Safety

NHC are also used regularly by law enforcement agents and forensic professionals to identify plant fragments, seeds, pollen grains, animal hair, or even soil samples linking suspects to the scene of a crime (NatSCA 2005). Reference materials from copper ore to cholesterol molecules have been collected and are curated in NHC to be used to verify the true identity of unknown samples (NSTC Working Group 2009). Insect collections are

particularly useful as sources of reference material for forensic entomology, the study of the insects that follow the sequence of decomposition (Rivers and Dahlem 2014). For example, identifying fly maggots present, and relating this to the biological succession of scavenging insects, can approximate the time of death of a partially decomposed body. The vast entomology collections at the UC Davis Bohart Museum were used by the FBI in 2007 to place a suspect at the location of the murder by identifying the insects and their geographic origin (NSTC Working Group 2009).

Public safety can also benefit from NHC in the prevention of hazards. A good example is the Svalbard Global Seed Vault, located in Svalbard, Norway. This seed storage facility was built to safeguard global food supplies (Asdal and Guarino 2018). It contains a duplicate sample of seeds from different plant varieties held in gene banks around the world, in case a natural or man-made disaster destroys common food crops (NSTC Working Group 2009).

Disasters happen unexpectedly. In 2001 a series of natural gas explosions in Kansas killed two people and displaced hundreds of others, but, thanks to the thousands of geological cores collected in the 1960s and properly curated in the Kansas Geological Survey, scientists were able to produce maps of the local geology within hours, and quickly advised the gas company where to drill holes to vent the leaked gas and prevent further explosions (NSTC Working Group 2009). Other geological materials collected in the past are being used to identify areas of greater seismological risk, and to take precautionary measures where resampling is impossible due to urbanization or environmental restrictions (NSTC Working Group 2009).

Local Communities and Their Identity

Policymakers often disregard the role NHC have in a local community's identity. The importance of this role should not be overshadowed by the global importance of larger NHC housed in national and international institutions (NatSCA 2005). Housed in the local museum or university, NHC contain local treasures, examples of local minerals, fauna, and flora of scientific value through their interpretation of the local environment and its protection. In many local communities, the study of natural history is often the focus of a very active local natural history society, where members enjoy collecting, know how to preserve specimens, and eventually bequeath well-identified specimens to local NHC (NatSCA 2005).

A local NHC benefits the local community directly, but it does so indirectly as well. For example, if exhibited in a museum, NHC attract tourists, create services, and boost the local economy (NatSCA 2005). Even NHC housed in an institution many thousands of miles away from the site where they were collected can provide benefits to local communities (Sholts, Bell, and Rick 2016). For example, field notes and audio-visual recordings collected 50 years ago have been used by native communities to revitalize languages such as Myaamia and Wampanoag, which were dormant for 50 years, empowering communities to respond to globalization pressures (Hinton 2011).

NHC can also have an impact on local communities if their central theme is a sensitive topic. NHC including human remains, in particular, deal with a specificity that raises many ethical questions, yet it is clear that such collections occupy a special place in local archaeological

and historical heritage (Cadot 2007; Van Praët et al. 2019). Understanding how and why these sensitive NHC were assembled is important in addressing societal issues, past and present. NHC must be available to the public, but always with care, for they can unwittingly revive a painful past for some local communities or create biased representations of cultural groups in a multicultural community (Nivart and Dumez 2016). The example of the Tsantsa heads of the Slovene Ethnographic Museum in Ljubljana, shows that museums are self-aware and self-critical about their role in the creation of cultural stereotypes and hierarchical relationships (Podjed and Bartulović 2012). Human remains in NHC are numerous (Cardoso 2006) and usually have a particular and highly regulated status: in the USA there is the Native American Graves Protection and Repatriation Act; in Australia, the Aboriginal and Torres Strait Islander Heritage Protection Act. Museums and institutions housing NHC are regulated by many laws (Rose, Green, and Green 1996; Seidemann 2004), which are essential if they are to address current societal issues.

Inclusion and Participation

NHC can be used to convey complex scientific messages to the wider public (Bensaude-Vincent 2010). The field of ecology emerged from the study of NHC (Benson 2000) and the message of the need for environmental conservation (arguably the most important societal issue today) can be facilitated thought NHC. Facilitating NHC through talks, workshops, exhibitions, interactive displays, or self-guided activities transforms content and expertise into learning experiences that reflect the needs and interests of each target audience (Dillon et al. 2016). Events and lectures using NHC certainly advance the greater public understanding and appreciation of nature (NatSCA 2005). The experience of the Grant Museum of Zoology, in London, has shown that the public is quite capable of providing information on NHC with the QRator project (Carnall, Ashby, and Ross 2013) and with other projects aiming at involving the visitor with the collections and their use within exhibitions. NHC, therefore, can be used to model scientific inquiry and to stimulate the curiosity about the natural world (Powers et al. 2014).

However, addressing societal issues is more complex than just the exhibition of NHC. For example, an exhibition on food poisoning was in line with the wider aim of promoting public understanding of science but conflicted in practice with the attempt to present the public with scientific information useful to them in their everyday lives (Macdonald and Silverstone 1992). Facilitation aims at finding the right medium for conveying scientific information to a large public, without oversimplification. NHC are formidable tools for sharing knowledge and can be used in many ways to involve people and create a cohesive social fabric and public well-being. Museums and other institutions housing NHC are providers of authoritative and unbiased science (Macdonald and Silverstone 1992), and yet policymakers often looks at them as interpretation centers where exhibitions are there to entertain the public with participatory activities. “Natural history museums,” however, “should not try to become theme parks (…) because a museum is not likely to be very good at being one” (Fri 1997).

This said, NHC offer opportunities for public participation. For a number of years now, citizen science has enabled audiences to participate in the process of scientific discovery along with specialists, an excellent way to engage the public (Wen et al. 2015; Miller-Rushing, Primack, and Bonney 2012; Wiggins et al. 2011; Bœuf, Allain, and Bouvier 2013). Citizen science allows people who are not professionals, but who may have substantial knowledge

about a particular field, to get directly involved in authentic scientific research (Le Crosnier, Neubauer, and Storup 2013). It brings together information collected by a large, dispersed group of observers to speed up ecological research at unprecedented spatial and temporal scales (Dickinson et al. 2012). At the National Museum of Natural History in Paris, France, numerous citizen science projects have been developed and grouped together in the "Vigie Nature" program (Julliard 2017). Initially launched in 1989, “Vigie Nature” today gathers more than 50,000 participants (ONB 2019) on every natural domain, experts as well as beginners. Even though it has scientific limits, citizen science is increasingly attractive for its societal benefits (Legrand et al. 2017), with no limit to its ability to raise awareness of environment conservation (Gosselin, Julliard, and Gosselin 2010; Dickinson, Zuckerberg, and Bonter 2010). It certainly allows for many memorable school trips, family outings and an inclusive and involved social fabric reconnected with nature!

Education through participation is an important step in learning about the environment (Tal and Morag 2007; Ramey-Gassert, Walberg, and Walberg 1994; Allard, Boucher, and Forest 1994; Powers et al. 2014). In 2005, the average secondary school biology teacher in England was unable to recognize more than three local wild plants (Bebbington 2005). But teachers can learn from NHC before taking their students to the field, and they could even get inspiration from them to develop topics that are not in the prescribed teaching syllabus. Many new vocations and ideas were born from a single visit to NHC (Feldman et al. 2012). NHC also represent an important resource for higher education training in identification, taxonomy, and classification. In 2009, only a minority of university students could identify common plants correctly (Leather and Quicke 2009), but many natural history museums have or are developing close links with a local university (NatSCA 2005).

NHC can have an inclusive role in audience accessibility: “tactile aesthetic accessibility can contribute to the learning of the blind and visually impaired” (Hopkins 2003; Kastrup and Sampaio 2012). In France, the National Museum of Natural History in Paris makes this type of experience available, and the Natural History Museum in Nantes allow visitors to touch the exhibited rocks (authors’ pers. experience). Inclusion can also mean that NHC can reach out for their public: during the years of closure for refurbishment, the Natural History Museum of Bordeaux took part of their collections to the road as a traveling exhibition (Mémoire 2014). Numerous initiatives are being developed with the aim of taking NHC to the widest possible community, in particular, the digitization of NHC (Blagoderov et al. 2012; Hill et al. 2012): putting NHC freely on-line allows the simplest access to the greatest number of people.

Inspiration for Art and Engineering

NHC can be assembled for their aesthetic value and can be a source of inspiration for artists, writers, and performers (Allmon 1994). For centuries, paintings, sculptures, and plays have been inspired by nature, but natural history objects have themselves been transformed into works of art. We will give two examples: Damien Hirst is a controversial contemporary artist renowned for his use of taxidermy and anatomy in his installations; Ellen Jewett makes extraordinarily realistic sculptures, which resemble taxidermy mounts and are definitely inspired by NHC.

However, creative people can take inspiration in NHC in a more practical way. Anatomical wax models, made for the purpose of recording pathological cases before the technological leaps of photography and video made it redundant, can be considered works of art (Ballestriero 2010). The many bird or plant identification guides that nature lovers take to the field are more often than not filled with drawings made by professional artists, who, it is often forgot, go to NHC for direct and close visual contact with the colors and forms of animals and plants they need to draw (Winker et al. 1991). Moreover, designers and engineers have tried to emulate aspects of the natural world by consulting NHC. For example, a top yacht designer spent much time studying tuna fish specimens as an aid to design faster yachts, and research into the reduction of air drag on aircraft has involved the study of shark skins held in NHC (NatSCA 2005). While a relatively spare application of NHC as it currently stands, this use should be explored in more future opportunities because it has the ability to impact a larger variety of museums, collections, and exhibitions.

Unanticipated Uses

Finally, NHC have constantly been used in ways and purposes entirely unanticipated even by the most broad-minded of curators (Lettie and Puckett 2002). One of them is training in business and management acumen. The variety of skills needed to properly conserve and curate NHC has been noted by industry recruiters who came to see them as a management and leadership training ground (Krishtalka and Humphrey 2000). Of course, NHC have always been used for training in identification, taxonomy, and classification, and for facilitating public understanding and appreciation of nature (Mujtaba et al. 2018; NatSCA 2005).

The argument of unanticipated uses is often made when curatorial staff feel the need to justify the existence of their NHC. Although it is perceived as a weak argument, it is, in fact, a poignant one: there have been so many cases of NHC being used for purposes so vastly different from the ones they were originally constituted, that we can never dismiss a collection when its original use is finished (NatSCA 2005). “Properly preserved specimens are useful for centuries” (Winker et al. 1991).

Conclusion

In this paper we attempted a brief overview of lesser-known uses of NHC that have resulted in benefits for health, economy, security, identity, and education that further public well-being, inclusion, and participation. NHC can provide major financial and social benefits to areas way beyond their traditional or original purpose. A majority of the examples discussed reveal that NHC are repositories of reference material (Winker et al. 1991). More like an archive of unique precious manuscripts than a library of newly bought books, each specimen in NHC is unique and cannot be replaced. NHC curators receive thousands of inquiries from local, national and international conservationists, researchers, planners, environmental health officers, customs officers and so on every year (NatSCA 2005). It has even been shown that, by housing voucher specimens, NHC can actually reduce the costs of scientific research (Bradley et al. 2012, 2014; Suarez and Tsutsui 2004), even though contemporary rates of voucher deposition have been described as alarmingly low (Turney et al. 2015).

Older NHC are still preserved today because they document the results of research, and allow earlier findings to be reproduced and confirmed (or rejected). They are re-analyzed

using new technology and methods to reveal information no one suspected they could carry, information that is of relevance to research in fields other than the one for which they were collected. New contributions of NHC are now more important to society than the original reason for going out and collecting specimens (Winker 2005). They provide evidence of long-term historical trends, allowing researchers to make predictions into the future (NSTC Working Group 2009).

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