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The tragedy of the Natural History Museum, London

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Abstract

The remit of the Natural History Museum, London, encompasses the whole of the natural world and places it at the forefront of global concerns about human impact on the biosphere. The Museum's stature as a world leading institution for storing and recording living diversity brings responsibilities, obligations and new prospects. In addition to revealing the genetic evolution of life in considerable detail, advances in molecular biology and cryogenics offer exciting new opportunities to extend beyond the Museum's traditional role as a storehouse for recording living diversity and to take a lead in biodiversity conservation.

In its strategy for the coming decade, the Museum has declared a planetary emergency for which we need an unprecedented response, asserting that we must act now, that we must act on scientific evidence and that we must act together. However, the Museum is no longer led by scientists; its relevant expertise and the prioritisation of its collection-based world-leading role is being rapidly dismantled. It has been taken over by an administrative structure and placed under a government Department that have no notion of the importance of this role. Much of the Museum's activity is no longer led by science intimately connected to its role as a collections-based institution and its public profile is dominated by journalistic presentations from sources that are widely available to a broad range of the media. Inappropriate leadership and recruitment have diverted its science base in directions that place much of its research within the activities of numerous other academic agencies, undermining the reason and justification for the Museum's existence. The move of about half of the collections and associated scientific staff to a location outside of London is a self-imposed act of institutional vandalism. It will mutilate a national treasure, not only inflicting a massive and permanent financial burden but also irrevocably damaging the Museum's, cultural identity and function as an integrated collections and research institution. Rather than responding to a planetary emergency, the Museum is tragically descending into irrelevance.

Key words: specimen collections, taxonomy, systematics, biodiversity crisis, human overpopulation, government culpability, DCMS, international collaboration, species conservation, biobanking

Introduction

The impacts of human numbers and human consumption are driving global environmental crises, most notably what is widely regarded as a new mass extinction event. This is a time for the Natural History Museum, London (NHM) to galvanise its considerable resources and scientific expertise and claim ownership of its priorities, obligations and emerging opportunities. The remit of the NHM encompasses the whole of the natural world. This includes Earth's history and changing climate, its mineralogy and geology, including meteorites, the record of the evolution of life preserved in its rocks and the nature and scope of living diversity. All of these fields of scientific endeavour are important. However, from its origins within the collections of the British Museum, which was founded in 1753, the NHM has been at the forefront of naming, storing and recording living diversity (the field of biological taxonomy), and investigating its relationships (the discipline of biological systematics). Research conducted at the NHM should be based on its collections. During a period of massive extinctions, the NHM's primary responsibility is clear. In response to the loss of the biodiversity that it stores and investigates, and in addition to research focussed exclusively on its collections, the NHM needs to build legacy collections, much of which will need to serve for all time. The NHM needs to grasp new capabilities for safeguarding living diversity by biobanking. By utilising advances in cryogenic storage of viable cells, the NHM can play a role that is far more important than anything that it has undertaken at any time in its history, contributing to retaining a biodiverse world for its own sake, and for humanity to experience, benefit from and enjoy.

However, rather than recognising and embracing the opportunity to take a lead in responding to the biodiversity crisis, in its *Strategy to 2031* (NHM, 2019, 2020a), the NHM is seeking to dismantle its world-leading role, dispose of its expertise, which is the foundation of its authority, and transform what it does. Delivered in the slick, hyperbolic style of a commercial marketing team, much of the content is merely aspirational virtue-signalling. It espouses a delusional vision of both people and the planet thriving. With a depleted scientific base, its mission to create advocates for the planet is an ambition

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akin to that of environmental campaigners, a critically important service but one more effectively provided by other agencies. Exploiting past prestige, the NHM's stature is shifting from a broad-based authoritative source on biological diversity towards a media agency lacking authority and valuing presentation over content. The NHM is blind to the reality of what is driving global threats to the biosphere. Despite declaring a planetary emergency, it is negligently deserting its vitally important and established scientific role. It is encroaching on a whole range of activities that may be valuable as academic pursuits and for human wellbeing but are largely irrelevant to the current catastrophe and overlap those of numerous other institutions and agencies.

Delivering on United Nations Sustainable Development Goals (UNSDGs) (U.N., n.d.) is presented by the NHM as an overarching framework for NHM objectives. This is inappropriate and completely misses the point about what the NHM can and should be doing. Numerous publications are devoted to explaining sustainable development (e.g., Daly, 1990, 2010; Redclift, 1987, 2005; Robert *et al.*, 2005; Vallance *et al.*, 2011; Brown, 2015), but it remains poorly defined and widely and routinely parroted to the extent that it retains little meaning. The Brundtland Commission introduced sustainable development from an entirely anthropocentric perspective: 'Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs.' (Brundtland Commission, 1987, Part 3, Section 3, paragraph 27). Concepts of development now come in many guises, ranging from a process of expanding human freedom (Sen, 1999) to an equivalence with economic growth. In fact, it can be argued that many of these concepts ultimately lead to growth. As a manifestation of growth, the concept is fundamentally flawed: there is no such thing as sustainable growth in a finite world. Many positive practices can be incorporated under the umbrella of sustainable development, such as developing circular economies that can ameliorate human impact (Suárez-Eiroa *et al.*, 2019). However, the notion that human numbers and consumption can be sustained without obliterating the natural world is a collective fallacy, a belief system with wide currency even in the most prestigious of scientific agencies. Despite demonstrable evidence that pursuing sustainable development does not have the capacity to save biodiversity, it is nevertheless promoted on the basis that UNSDGs remain a holistic framework for guiding priorities, including those for saving biodiversity (for example see *Nature* Editorial, 2021; *Nature Sustainability* Editorial, 2022). However, and regardless of any merits of UNSDGs and debates on sustainable development, the NHM has a distinct heritage and clear responsibilities. Many UN goals are completely outside the NHM's established remit and UNSDGs have nothing to teach the NHM about its role. UNSDGs are high on aspirations but have failed to provide pathways to delivery—crucially, they will not stop the current extinction crisis, which is what the NHM needs to urgently address and respond to.

How the NHM has been undermined and steered onto a path devoid of relevant ambition is a harrowing disaster for anyone who cares deeply about a once magnificent institution. More than that, its service to the natural world and to humankind has never been needed more. The massive loss of expertise at the NHM has demonstrated that it is simply not possible for the Museum to engage with everything it proposes without diminishing its core activity. That its primary role has been lost in a myriad of box-ticking objectives and that the unparalleled opportunity to contribute to the biodiversity crisis is ignored, are simply tragedies. These are extremely grave charges and the tragedy of the NHM cannot go unchallenged.

Collections: historical and modern

The NHM's collections are the core of its being and the lifeblood that sustains its existence. Only a tiny proportion of the collections are used for public exhibition. In contrast, the scientific reference collections are outstanding treasures of global significance that capture something of the natural world that we and earlier generations were born into. They are in many ways irreplaceable. Nevertheless, wonderful and priceless as these collections are, they are largely about the past history of collecting. They must be studied, safeguarded and cherished, but not be allowed to constrain the urgent need to build new collections that can not only serve as a legacy for future generations of scientists but contribute directly to saving biodiversity (Holt, *et al.*, 2004; Lerman *et al.*, 2009; Ryder and Onuma, 2018; Naggs and Raheem, 2014; Naggs, 2017, 2019; Gill, 2022; Mackenzie-Dodds, 2022; Bouwmeester *et al.*, 2022). Look anywhere in the NHM's biological collections and it is apparent that, for most groups, the great majority of collections were accumulated in the nineteenth century (Table 1, Table 2). By modern standards many were at best poorly preserved, poorly documented, and largely unsuitable for new methods of analysis. However, the value of historical collections is complex. For example, a large proportion of the fish collections of some 800,000 specimens are preserved in spirit and have lasting value for studies in morphology. Conversely, the estimated 8 million specimens of Mollusca consist largely of empty shells, which greatly limits their value in systematics and taxonomy. Nevertheless, such shells are an invaluable resource. They form the historical foundation of molluscan taxonomy and systematics and are a record, if often flawed, of species' past occurrence. The value of such collections is wide ranging, such as in providing time series, and new and unexpected uses are routinely discovered. For example, the value of historical specimens for determining historical climates from isotope ratios (Leng *et al.*, 1998; Rangarajan *et al.*, 2013; Ghosh *et al.*, 2017) could not have been imagined when they were collected. However, any notion that such collections should form the main museum legacy of living diversity for all future generations is preposterous.

TABLE 1. Selected annual acquisitions of zoological specimens in taxonomic categories for the 22-year period from the move to South Kensington in 1883 until 1904, 1904 being as far as *The History of the Collections* covered (BM(NH), 1906). A detailed breakdown of acquisitions was not given for the Mollusca, which by 1904, was determined as being 473,000 specimens (Smith, 1906). Acquisitions between 1856, when zoology was established as a department, and 1895 were provided by Günther (1912), although these were only provided as total acquisitions. Günther (1912) also provided the values of annual grants for purchasing new specimens. For example, the grant to the Zoology Department for 1888 1889 was £1800, which is equivalent to about £250,000 (based on UK inflation calculator). Interestingly, an appeal in the Museum's public galleries in about 2010 for funding field collections was very generously supported (£100,000+). Inexplicably, the appeal was not repeated.

Year	Mammals	Birds	Reptiles	Amphibians	Fish	Insects	Echinoderms
1883	225	1,056	379	129	1,373	22,848	294
1884	462	5,274	379	389	551	34,991	166
1885	755	90,551	754	298	485	17,467	250
1886	380	4,020	574	554	486	21,609	513
1887	396	25,206	899	553	1,248	18,166	241
1888	700	22,408	632	281	1,569	7,068	978
1889	366	11,105	859	288	6,130	37,508	814
1890	422	7,147	643	258	1,587	45,081	2,240
1891	827	12,883	760	688	1,772	20,707	326
1892	939	11,156	764	578	1,582	48,028	1,034
1893	782	11,426	816	419	1,599	106,591	352
1894	1,206	6,273	1,259	545	901	39,096	90
1895	1,006	10,561	1,448	670	670	27,463	49
1896	540	21,900	886	647	1,004	7,4481	84
1897	2,330	12,783	1,873	741	1,359	4,4069	255
1898	2,161	6,842	892	656	2,111	15,731	1,527
1899	1,702	15,429	939	297	1,128	6,2042	121
1900	1,784	6,447	457	237	1,144	33,719	1,357
1901	1,923	19,358	681	687	1,265	116,545	178
1902	1,935	8,628	878	681	1,685	2,8031	139
1903	2,623	9,576	1,271	670	1,744	9,4429	93
1904	2,461	17,903	969	607	1,530	3,7316	382
22-year Total	25,925	33,7932	19,012	10,873	32,923	952,986	11,483
Annual Average	1,178	15,360	864	494	1,497	43,317	522
Total holding in 1904	54,807	c.400,000	?	?	?	?	?

As someone who has perhaps arranged more collections-based international collaboration than anyone else at the NHM, I know that excellent levels of international cooperation can still be achieved, but such collaboration needs to be nurtured and based on shared desires both to record and save living diversity (Naggs *et al.*, 2006; Naggs and Raheem, 2009; Naggs, 2017, 2019). Claims in *Strategy to 2031* that the NHM has an ambitious collections acquisition programme are a fiction. The numbers cited are meaningless without a detailed breakdown. The fact remains that the NHM does not have targeted and ambitious programmes to collect from non-marine habitats in tropical biodiverse countries, which are in the frontline for extinctions. This is a clear dereliction of its duty to future generations. The NHM's ad hoc collecting model is completely inadequate in the face of current extinctions and collecting for research projects without engaging internationally with governments, local scientists and communities is no longer tenable. Such an engaged approach is appropriate for all natural history resources, including fossil material (Christakou, 2015; Lenharo and Rodrigues, 2022). However, there are instances where brutally dysfunctional regimes prevent scientific collaboration, leaving international scientists in a quandary as to how to deal with precious scientific resources such as 100-million-year-old treasures preserved in Burmese amber. Safeguarding and researching such wonderful material is an ethical minefield (Sokol, 2019; Rayfield, *et al.*, 2020; Haug *et al.*, 2020; Engel, 2020; Peretti, 2021). Nevertheless, the overriding consideration

TABLE 2.
Selection of current holdings of animal groups.
No data comparable to that in *The History of the collections* was published for the zoology collections later in the twentieth century. Summary information for some groups has not been published. Records are held in the mostly hand written registers, which have all been scanned. Many are detailed but the quality varies from group to group. Current new acquisitions are databased and historical material is being added to the NHM Data Portal, often in response to requests for information (NHM n.d.1) or following publications that refer to NHM material. Many of the twentieth century acquisitions were of collections of nineteenth century or early twentieth century origin and, apart from specimens obtained as grant funded research, this continues to be the case (although the number of private collectors providing material has dwindled significantly). The current estimate for zoological holdings (including insects) is 63 million specimens and for botany, 6 million specimens (NHM, n.d.2; NHM, n.d.3; NHM, n.d.4). Of these estimated 69 million specimens the NHM Data Portal records some 4 ¼ million samples. The geographical coverage of marine, freshwater and terrestrial biotas is global with particularly strong representation from Britain's colonial empire. The NHM asserts that it holds the world's most important natural history collection, with greater systematic coverage and more types than any other museum (NHM, n.d.5). However, the dwindling number of curators over the past few decades means that even the most basic maintenance of the collections has been neglected in many areas and time and resources have rarely been available for publication of catalogues and reviews of the collections.

	Mammals	Birds	Herpetofauna	Fish	Insects	Echinoderms	Mollusca
NHM Specimens	400,000	1,000,000+	200,000	800,000	34,000,000	65,000	8,000,000
Number of recognised species in world	c.4,700	c. 10,000	c.20,000	c.35,000	<1,000,000?	c.7,000	c. 85,000
Percentage of known species in NHM	70%	95%	?	?	?	50%	c.90%+?
NHM Type specimens	8,000	9,000	8,000	12,000	?	6,500	66,000

with such material must be that it is not allowed to be lost to science and future generations.

In a changed world and following a revolution in scientific methods, the NHM needs to change its whole approach to building collections for the future, not focussing on past collections. Our understanding of biological diversity has been transformed by computer power, developments in molecular biology, in imaging and methods of analysis, while satellite-based global-positioning systems provide precise georeferenced locality data. The priority of focussing on historical collections and setting them in stone as the heart of the NHM's collections for the future is completely unacceptable, introverted and backward-looking. This approach is exemplified by a time wasting, box ticking collections management programme borrowed from the Smithsonian Institution (Wilson *et al.*, 2018). Named 'Join the Dots', the notion that this 'management tool' can, for example, be used to identify gaps in the collections for prioritising new acquisitions, demonstrates just how utterly the NHM's senior management team for collections is misguided and detached from the reality of what is happening in the outside world.

We cannot predict the full extent of how collections might be used in the future but a new and ambitious model is required for collections that also encompasses the full scope and potential of molecular material. This needs to be based on biocentric priorities and a commitment to identifying shared objectives with nations, institutions and individuals across the world. Expertise and resources are not evenly spread and there is an urgent need to build and sustain relationships, and to develop local expertise, particularly with biodiverse countries (Ebenezer, 2022). Surveying and collecting led by outsiders in a host nation are insensitive at best and expedition-style collecting led by outsiders is a toxic model reminiscent of an outdated imperial approach. Institutional commitment to establishing and sustaining relationships on biodiversity does not exist at the NHM. Responses to opportunities have been ignored, inept or not sustained beyond the input of a few committed individuals. Such relationships are fundamental to developing a global, coordinated response to building collections around the world, both for the international scientific research community and for supporting a global network for molecular methods of conserving species and genetic diversity within species. Collaboration means spending less time achieving metrics of performance and more time nurturing relationships (*Nature* Editorial, 2021): in a global emergency we need to work together.

Global geographical priorities

There are straightforward, simple and unambiguous criteria for setting geographical priorities for the biodiversity crisis based on:

- The level of native biodiversity
- The degree of endemism and distinctive components
- The level of extinction threat

Although some nations may consider that they are self-sufficient in their resources and breadth of expertise, there is always scope for international collaboration. The NHM is an institution of global stature with a global remit, yet *Strategy to 2031* declares that engaging with biodiversity begins at home and sets UK Biodiversity as its first listed Focus Area (the others being 'Lessons from the Dinosaurs' and 'Age of Humans'). The early experiences of encountering local biota can inspire a sense of wonderment, instilling a lifelong passion and concern for the natural world. However, Britain is largely irrelevant to the planet emergency that the NHM identifies. Wide dissemination of information about what is happening in the wider world has extended public awareness to global perspectives that earlier generations lacked. The terrestrial and freshwater biota of Britain is a subset of the Continental biota, periodically wiped out in glacial episodes and recolonised in interglacial stages. Its endemism is negligible. On a global scale of biodiversity priorities, it is very low indeed. For all its emotive words on the biodiversity crisis, the NHM is focussing disproportionate efforts on British biodiversity, when the biodiversity crisis, measured by extinctions, is taking place elsewhere.

Of course, those of us who live in Britain celebrate and cherish our biota and are deeply concerned by its significant impoverishment and the threats that it faces. As individuals and through numerous group initiatives, many NHM staff are actively engaged in promoting the understanding and conservation of the British biota. A passionate interest and concern for our biota has a long history. The British biota is extremely well served by both professional and amateur naturalists, possibly more so than anywhere else on the planet. Research projects and conservation efforts relating to the British biota are undertaken in British universities, and numerous agencies have a specific remit for British biodiversity, such as citizen scientists and a host of specialist and local societies. There are active national groups such as the British Trust for Ornithology and the Royal Society for the Protection of Birds, which alone has 1.1 million members; local groups such as the 43 wildlife trusts have 850,000 members, while the Field Studies Council concentrates on education and particularly on engaging young people with the natural world.

What is driving the NHM's lack of ambition and parochial approach to the biodiversity crisis? It seems to be partly an opportunistic desire to take advantage of these existing and very large constituencies of British naturalists, assuming the status of an umbrella role, and also the result of fulfilling the Convention on Biological Diversity's (CBD) obligations for national action. In addition, it is an approach driven by public-engagement posturing rather than scientific priorities. The priority need for such national oversight is highly questionable and, to be of value, it would carry an administrative burden that the NHM cannot possibly afford if it is to fulfil its global and more demanding obligations. The extensive NHM collections of British species are an important resource, but devoting disproportionate resources and staff effort to the British biota and seeking to lead in protecting urban nature (NHM, 2019, page 17) are indulgences that cannot be justified when so many other agencies are already involved. The NHM has wider, more challenging and neglected responsibilities. British urban nature is irrelevant to the scale of biodiversity loss globally and the fact that nearly all extinctions are taking place in the tropics.

Collaborating with twelve institutions (Wellcome Sanger Institute, n.d.), including the Wellcome Trust, and the Royal Botanic Gardens Kew, the NHM celebrates its involvement with The Darwin Tree of Life Project (NHM, 2020b). The project is a massive undertaking that requires identification skills that are largely lost at the NHM. Contributing to the hugely ambitious Earth BioGenome Project but dealing solely with British biodiversity, it involves the processing of some 66,000 British species, supposedly within two years. Driven by anthropocentric academic curiosity the Earth BioGenome Project and the Darwin Tree of Life Project disastrously stop short of preserving viable cell lines and making a significant contribution to saving living diversity (Lerman *et al.*, 2009; Ryder and Onuma, 2018; Naggs, 2017, 2019). The results of these investigations might be fascinating for academics, but grandiose justifications for this undertaking are spurious (The Darwin Tree of Life Project Consortium, 2022), and highlight yet another missed opportunity. Biodiversity loss measured by large-scale extinctions is taking place in a different arena and the Darwin Tree of Life Project is a clear example of displacement activity.

Furthermore, and despite all of the interest and efforts made towards conserving Britain's biota, the effects of industrialised farming and chemical use in such areas as golf courses and domestic gardens are not mysteries; they create biodiversity deserts and contaminate rivers and groundwater. Their impact is severe and far reaching beyond their boundaries. Much of the 35% of Britain that supposedly has some measure of protected status is directly exploited for agriculture and much of the remainder is directly or indirectly affected by chemical agents (Goulson, 2021). These are the areas that British conservationists need to target and the NHM highlight. This is part of a global problem. Insecticides, herbicides, nutrient supplements and light pollution are some of the recognised factors devastating insects in particular, and the web of life that depends on them (Hochkirch, 2016; Hallmann *et al*., 2017; Vogel, 2017; Lister and Garcia, 2018; Sánchez-Bayo and Wyckhuys, 2019; Janzen and Hallwachs, 2021; Goulson, 2021; Wassen *et al*., 2022)).

Marine biodiversity

Despite human pressures imposed on marine life, marine ecosystems have been stressed but so far remarkably robust and largely capable of recovery. Recorded human-driven marine extinctions have remained relatively low (IUCN, 2021; Cowie *et al*., 2022). However, human pressures have rapidly intensified. Coastal margins have been transformed, industrialised fisheries devastate marine life and chemical and physical pollutants reach every extent of the oceans. Increased CO_2 levels increase the acidity of the seas and extensive mining of the ocean floor is in prospect. Many fear that marine ecosystems are at imminent risk of collapse (Dryden and Duncan 2021). In addition, much marine life still remains to be discovered, notably in the deep ocean (Bouchet *et al.*, 2016; Glover *et al*., 2018). Although the immediate extinction crisis is in our own terrestrial realm and the freshwaters that we contaminate and exploit, we clearly cannot be complacent about marine life. If marine life is to follow non-marine life with ecological collapse and large-scale extinctions, then there is a similar if currently less urgent need for safeguarding marine diversity by building collections of cell lines (Rawson *et al.*, 2011).

World in crisis

In responding to the planetary emergency, it is critically important that the nature of the biodiversity crisis is understood, set in context and not invoked in support of actions that may be of immense interest, be worthy of pursuit and of academic value but are largely irrelevant to saving biodiversity. For the NHM it is also essential that it engages fully with the valuable activity intimately linked to its collections. The natural world is experiencing levels of extinctions that have not occurred for tens of millions of years, long before hominids evolved (Diamond, 1989; Whitten *et al*., 2001; Ceballos *et al*., 2017; Hughes, 2017; Lister and Garcia, 2018; Brondizio *et al*., 2019, 2021; Goulson, 2021; Cowie *et al.*, 2022). However, specific and detailed knowledge of these extinctions and projected extinctions is very limited and is largely confined to vertebrates (Ceballos *et al*., 2020; Cowie *et al*., 2022), which probably account for significantly less than 1% of animal diversity. Much reliance is placed on the IUCN Red List as a 'Gold Standard' for assessing biodiversity extinctions and extinction risk. Unfortunately, the capacity for the Red List to perform this role is overrated; it can provide only very limited and highly biased information on a tiny proportion of living diversity. All known birds and amphibians have been subjected to evaluation and 91% of mammals. This has been an enormous undertaking but, even with mammals, the reliability of data is questionable. Project Tiger has been running for approaching half a century. It is worth emphasising that even for one of the world's largest terrestrial predators, for which many millions of pounds have been spent on studying and conserving fewer than three thousand individuals, determining accurate data on the number of tigers in India has proved to be difficult (Karanth, 1995; Karanth *et al*., 2017; Mazoomdar, 2019; Naggs, 2019). Nothing like as much effort has been expended on the majority of mammals. With such unreliable data for one of the most iconic and well-studied vertebrate species, how can we possibly know details of what is happening and has happened to the numerous invertebrates that occupy or once occupied disappearing tropical forests? In a random sample of Coleoptera, 13% were known only from a single individual specimen and 53% were recorded only from a single locality (Stork, 1997); it is clear that a vast number of insects and other invertebrates have not been described. Estimates of the number of insect species have varied widely (May, 1978; Gaston, 1991, Stork, 1997). However, an estimate of up to 50 million insect species (Stork, 1997) is now recognised as being an enormous overestimate. Estimates based on refined methodologies have given a total of 5.5 million species of insects and an additional 1.3–1.5 million other terrestrial arthropods. Over one million insect species have been described (Zhang, 2011, 2013) but many described species are junior synonyms of species that have already been described (Stork, 2018). Thus, although the number of currently recognised biological species to date has not been comprehensively revised, the figure will be well under one million (Table 2). In any event, it clear that millions of species have not been described and named and it is inevitable that overall species losses are largely unrecorded, particularly on continental land masses. The lack of hard data and the distorted bias present in red listed systematic coverage has led some to misunderstand the reality of an extinction crisis (Lomborg, 2001; Briggs, 2016, 2017; Richardson, 2019; Lees *et al*., 2020).

While providing a much better picture of the scale of extinctions than red listing, the most sophisticated modelling based on species-area relationship and habitat loss can do little more than provide elegant presentations of what is largely self-evident. Ambitions and attempts to provide comprehensive hard data for invertebrate extinctions are counterproductive because we patently cannot achieve them. Raising expectations that detailed data on the scope of extinctions can be attained opens up all manner of problems. We need to build an information base but avoid distractions over unachievable detail and concentrate on the overall picture, which could not be clearer. For those of us haunted by having witnessed the burning of tropical rainforests from horizon to horizon, or the ongoing obliteration of Southeast Asia's isolated limestone hills that were rich in endemic species, the massive loss of terrestrial habitats and their associated biota are indisputable. No one should lose sight of this incontestable reality (Cowie *et al.*, 2022). It is exemplified by the comprehensive forest loss in Sumatra within just a few decades (Whitten *et al*., 2001; Naggs, 2019; Nikonovas *et al*., 2020). We helplessly observe the tragically rapid destruction of Madagascar's wonderful and unique biota, driven and accompanied by human poverty, starvation, political turmoil, climate change and rapid population growth (Ganzhorn *et al*., 2001; Clark, 2012; USAID, 2021; Waeber *et al*., 2016; Salmona *et al*., 2017; Naggs, 2019; Ratsifandrihamanana, 2021).

In a review from a palaeontological perspective Barnosky *et al*. (2011) addressed the issues of what qualifies as a mass extinction and what timescale is required to qualify as a mass extinction event. They characterised five previous mass extinctions as episodes in which more than three-quarters of the Earth's species were lost in a geologically short time, typically less than 2 million years. For the timescale of the current extinction event, Barnosky *et al.* considered the past 500 years for their analysis, which is in keeping with the IUCN's starting point for recording human driven extinctions. Whilst it may convey a sense of the magnitude of current extinctions in the context of Earth history, considering the current situation as a mass extinction event comparable to the 'big five' does not characterise the nature, speed and scope of what we are facing today. This results in confused and confusing discussions of extinction events that fail to recognise the current picture. For example, Vaidyanathan (2021) refers to one projection suggesting that we are indeed facing the sixth mass extinction in the geologically short timescale of 14,000 years, in which case we might feel inclined to relax and forget about it. Others suggest a timescale measured in decades. We need to be aware of what is happening to biotas now and can foresee in the immediate future; beyond that is the realm of science fiction.

There is a significant body of obfuscating information that masks the basic truths. For example, Vaidyanathan (2021) cited widely disseminated research based on measures of biodiversity that include alien exotics. Research based solely on undifferentiated insect biomass, cannot be used to quantify biodiversity resilience. Citing plant species as increasing in local areas when they include introduced naturalised species is a measure of the disaster of introducing exotics at the expense of a unique biota. Examples include plant species having doubled in New Zealand since occupation by humans and a 25% increase in forest species in Eastern Canada following the arrival of Europeans (Boyle, 1992; Vaidyanathan, 2021). In addition to introduced exotics, there is the added process of disturbance resulting in pioneer species' encroachment into climax forest communities, appearing to increase their species richness. Uncritically invoking overall species diversity as a positive outcome is a bizarre notion of species durability. Such reports do not contribute to investigations measuring biodiversity loss through extinction.

A profoundly important phenomenon that affects human perception of what is acceptable is the psychological and sociological phenomenon known as shifting baseline syndrome (SBS). With ongoing environmental degradation at local, regional, and global scales, people's recognition of what constitutes 'normal' is progressively lowered (Soga and Gaston, 2018; Jones *et al.*, 2020). Even changes that occur in individual's lifetimes are often accommodated and not recognised. Notably, each new generation tends to accept the situation in which they were born and lived through as normal; a similar phenomenon of degradation and failing to recognise it can be applied to institutions.

While habitat loss and degradation in non-marine habitats are the main drivers of extinction, other processes driven by human numbers, population density and speed of movement on intercontinental scales are major factors driving extinctions. The spread of exotic alien species through human agency is driving extinctions, rapidly homogenising biotas and changing the course of evolution (Naggs *et a*l., 2003; Naggs and Raheem, 2005; Capinha *et al*., 2015; Olden *et al*., 2016). Some consider that this process is not only inevitable but should be embraced (Pearce, 2016; Thomas, 2017). Whilst it is true that the history of life has involved considerable mixing of biotas as geographical barriers change over time, the rapid world-wide mixing and homogenising of biotas through human agency greatly diminishes global biodiversity and should be rejected as a satisfactory legacy for future generations (Hettinger, 2021).

Emerging diseases that were no doubt frequent but most often localised and unrecorded in the past are not confined to humans and can affect all life forms. A catastrophic example being the global spread, doubtless facilitated by human agency, of the virulent fungal pathogen chytridiomycosis that is responsible for serious declines and extinctions of amphibians, posing the greatest threat to biodiversity of any known disease, resulting in more than 40% of the 6,300 amphibian species being threatened with extinction (Berger *et al*., 1998; Wake and Vredenburg, 2008; IUCN, 2021). Cryogenic conservation measures for amphibians offer the only means of saving such large numbers of species (Kouba, 2013; Zimkus *et al.*, 2018).

International efforts such as the Convention on Biological Diversity (CBD) and the United Nations Sustainability Goals have not provided pathways to halt biodiversity loss. World governments' targets set in 2002 to significantly reduce the rate of biodiversity loss by 2010 completely failed (CBD, 2010). None of the CBD's following 20 ten-year targets, the Aichi biodiversity targets (CBD, 2011), were achieved (CBD, 2020). One consistent feature of Conferences of the Parties (COP) of the CBD is the ever more ambitious objectives, even though earlier more modest objectives have not been achieved. For example, the failure of the 2011 Aichi objective of protecting 17% of the planet's surface has not constrained the setting of a new target, at the 15th COP in Kunming China in October 2021, of protecting 30% of the world's land and sea areas by 2030.

To state that progress on biodiversity protection has proved elusive since the first 'Earth Summit' in Rio de Janeiro in 1992 (*Nature* Editorial, 2021), is an understatement that does not approach the magnitude of failure. A whole range of agencies exemplified by the CBD, World Wide Fund for Nature (WWF), the International Union for Conservation of Nature (IUCN) and lately the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) have failed even to reduce the rate of biodiversity loss; species extinctions are inexorably increasing. While recognising humanity's unsustainable consumption, none of these agencies actively acknowledge that current and projected human numbers are such that the scale of human existence and a biodiverse world are incompatible. As we struggle to find long-term solutions, we are trapped in an unsustainable position given human population trends, and will remain on an even less sustainable trajectory into the immediate future. It is not a question of doom-mongering (Knowlton, 2017; NHM, 2019, page 26)—this is the stark reality.

The CBD has also inadvertently promoted bio-nationalism, which has hindered international cooperation (Naggs, 2017, 2019; Britz *et al.*, 2020). The requirements for national signatories of the Convention to develop and enact National Biodiversity Strategies and Action Plans (NBSAPs) has hindered efforts to address international and multilateral priorities. For example, wealthy nations such as Britain, which have negligible biological endemism, have made more effort with national action plans, even if they have not been adequately implemented (Office for Environmental Protection, 2022), than in contributing to international objectives for conserving species. In keeping with this, and instead of taking a global perspective on biodiversity, the NHM mindlessly accepts this national prioritisation that Britain has signed up to with the CBD.

Every effort must be made to mitigate the pace and scale of extinctions and the numerous conservation activities around the globe should be acknowledged and commended. However, there can be no doubt that a major phase of extinctions will progress (Cowie *et al.*, 2022). Some fundamental soul searching is needed to devise a way forward. The NHM is not alone in needing to consider options that recognise this; but it is one of very few institutions that is well placed to act by building collections of cryogenically preserved species and genetic diversity on a large scale. We have to look beyond current horizons, to a future when circumstances will allow for the restoration of habitats on a scale that is commensurate with restoring a biodiverse world.

Climate change and biodiversity loss

In addressing the global emergency, the NHM recognises that climate change will have a major impact on the natural world. Together with other museum fossil collections, the NHM's palaeontological collections have made a major contribution to understanding not only the history of life but also the history of climate. They have demonstrated that climate change is an integral part of Earth history and that climate change has often occurred very rapidly (National Research Council (U.S.) Committee on abrupt climate change, 2002). Biodiversity is sensitive to climate change. Natural longer-term solutions are significant evolutionary adaptations to changed conditions; on shorter timescales both genetic, epigenetic, and behavioural changes might be involved but on all temporal scales, including in the short term, survival might be dependent on distributional change. There may be many constraints but, broadly, marine organisms have tracked climate change through latitudinal and ocean current changes. Examples of key groups for investigating distribution changes in marine environments are the tiny planktonic foraminifera, bivalves and corals. They demonstrate that the ranges of many marine species are often able to respond rapidly to major changes in response to climate change because there are relatively few barriers to dispersal and many marine groups have tiny pelagic larvae, facilitating dispersal. In contrast, terrestrial groups in their response to climate change, encounter numerous barriers to dispersal, such as seas, rivers, mountain ranges and deserts. These pose obstacles as species follow their climatic range of tolerance by means of latitudinal and altitudinal shifts in distribution. In some cases, habitats are being eliminated by climate change. For example, the need for increasing altitudinal range extensions for montane cloud forest to exist in Costa Rica in response to global warming. This is blocked by the insufficient height of existing mountains. As montane cloud forests are eliminated, their associated species become extinct (Freeman *et al.*, 2018). Impressive forest restoration programs in Costa Rica are commended (Earth.org, 2021). The Costa Rican government's ambitious commitment to a 10-year project, BioAlfa, to DNA-barcode Costa Rica's estimated one million Eukaryote species is a pioneering step for recording a tropical nation's biodiversity (Janzen and Hallwachs, 2021). Nevertheless, large-scale extinctions persist and the impact of climate change in Costa Rica has been linked to extensive extinctions in a wide range of habitats (Janzen and Hallwachs, 2021). Climate associated sea-level changes have had a major impact on both marine and non-marine species distributions, including the opening and closure of land connections.

A major difference between past episodes of climate change and the current human-induced global warming is that natural terrestrial habitats have been extensively fragmented and surrounded by a matrix of human-transformed land, which impedes or prevents distributional change. Many terrestrial species in fragmented habitat islands are effectively trapped by insurmountable barriers to relocating in response to climate change and they will go extinct. Thus, the current human-driven global warming will drive a new cascade of terrestrial extinctions in addition to the annihilation that is currently taking place through habitat loss. The obvious solution is establishing or saving habitat corridors. A clear distinction needs to be made between ecosystem corridors and corridors that act as pathways for animals such as mammals that avoid farmed areas, or tunnels under roads for smaller animals such as amphibians (Naggs, 2022). The time required and degree of success for newly planted corridors of native trees to develop as ecologically functioning corridors is a critically important area of research that needs to be developed. It takes time, adding to the urgency of putting such schemes in place. The NHM can play an important role in making use of its collections for facilitating the monitoring of species penetration into corridors. Much tropical forest has been influenced by some measure of human activity and there is a transition from primary to highly disturbed forests and converted forest that provide a range of habitats for a diminishing range of endemic species (Lunt and Spooner, 2005; Gardner *et al.*, 2009; Chazdon *et al.*, 2009; Szabó, P., and Hédl, R., 2011). In addition, some transformed habitats such as traditional home gardens can act as partial surrogates of secondary forest, hosting a subset of forest species and having an important role to play in conservation. However, such biotic friendly land use is also diminishing as farming practices become more intensive. Using the NHM collections as a foundation for identifying species and analysing their survivorship in a range of tropical forest and transformed habitats has been exemplified by collaborative work in Sri Lanka (Raheem *et al.*, 2008, Raheem *et al.*, 2009; Triantis, 2009). In relation to the scale of habitat loss and what would need to be done to make a significant difference, the construction of forest eco-corridors has been on a very small scale. Nevertheless, a number of examples demonstrate that tropical rainforest corridors can be initiated. Notable examples are in North Queensland where TREAT, a community-based tree planting group was formed in 1982 and has a membership of over 500 volunteers (Burchill and Cranesnorth, 2020). A small but significant step in Sabah is a WWF-Malaysia project to convert a small area of an existing oil palm plantation to establish a corridor (Miwil, 2021) and the Rhino and Forest Fund in Sumatra has purchased an area of oil palm to plant a native tree forest corridor (Hance, 2020). The most ambitious corridor concept is to establish the Araguaia Biodiversity Corridor in Brazil as the world's longest forest corridor 2,600km long and up to 40km wide but to date it exists only as a pilot project (Lewis, 2021). Rather than remedial action, it would of course make sense if from the outset, when forests and other natural habitats are converted for exploitation, that there were local dimensions to conservation and practices are imposed with areas of natural habitat protected and natural corridors left in place. With government support, the cooperation of companies and intensive lobbying of NGOs, notably Greenpeace, bold pioneering efforts have been adopted in Gabon to protect tropical forest biodiversity when developing oil palm plantations. Efforts include "Zero deforestation" when producing palm oil by developing degraded land rather than natural forest (Jong *et al.*, 2021; Lyons-White *et al.*, 2022). Restoration efforts demonstrate that tropical rainforests might be strategically restored by governments, NGOs, local activists and commercial groups acting together. Nevertheless, the reality is that most forest fragments are disappearing and the value of small forest fragments as reservoirs of biodiversity is rarely acted on. For example, numerous precious fragments of forest in Sri Lanka (Naggs, 2019) have recently had protection removed (Raheem, 2020; Samarasinghe *et al.*, 2021) and are destined to be lost. These are not just private, local issues—they should concern us all and receive international attention.

False message of hope

Strategy to 2031 (NHM, 2019, page 4) indulges in gushing optimism—"a future where people thrive, we need to offer people hope: hope that with the aid of good science and good policies, there is **a future where both people and the planet thrive**". How can there be a thriving planet when living diversity is being obliterated by human numbers and human activity with every day that passes? The NHM's symbol of hope for living diversity is 'Hope' —the name given to a Blue Whale skeleton moved from a side gallery into the Museum's central hall. It is held up as being an example of what can be achieved in saving living diversity. Blue Whales are the largest animal species known to have existed and that they have rebounded from near extinction is to be celebrated. Stopping the killing of Blue Whales was sufficient to save them—at least in the short term, and despite global contamination of the seas with plastics and chemical pollution. Blue Whales are certainly an iconic species but they are nevertheless a poor example of success in species conservation that cannot represent any overall hope for living diversity. A halt to the wholesale loss and degradation of non-marine habitats is not in prospect and it is through their uncontrolled loss that nearly all recorded and estimated extinctions are currently taking place. The unpalatable reality that the NHM shockingly denies, or at best ignores, is that its current approach cannot offer hope for the wide breadth of living diversity. The NHM's mendacious message of hope—that the show can go on—infantilises the public by assuming that they will only engage with optimistic messaging. It is an insult to public intelligence that further damages the NHM's scientific reputation. The magnitude of this disgraceful deception is magnified by the fact that the NHM is one of the few institutions of global importance that could act positively and on a scale that is proportionate with current biodiversity loss. False messages of hope must be called out but there are urgent and positive steps that can be taken, not just that some local conservation efforts will undoubtedly succeed, but in the application of scientific advances that offer new opportunities for storing living species for the future restoration of biodiversity in natural habitats.

Strategy to 2031 states (NHM, 2019, page 4) that: "We cannot hope to develop solutions to address problems such as habitat destruction, ocean acidification and the loss of coral reefs without research that unlocks the underlying biology and applied science. Understanding life on our planet is the greatest scientific challenge of our age." Understanding life on our planet has always been a NHM core research activity. Investigating how life interacts with climate change and geological processes such as plate tectonics and establishing ancestor-descendant relationships and distributions through time have been central to collections-based research—both of fossil and extant biota. The collections of both extant and fossil species are the essential foundations for this field of knowledge. Thus, there is nothing new in pursuing these objectives: they were already being pursued long before Darwin's 1859 *On the Origin of Species* was published, even if the mechanisms that drove the evolution of living diversity and the movement of continents were not understood. Nevertheless, however worthy and important as such research may be, it is not a route to solutions for arresting the destruction of non-marine habitats. For example, informatics is a rapidly developing and exciting field of information processing of huge datasets that, applied to biology, is closely linked to phenomics. The development of quantum computing offers new dimensions for these fields (Marx, 2021). Similarly, while genomics—the structure, function, evolution, and mapping of genomes, can be an important conservation tool for the relatively very few species selected for management practice (Hogg *et al.*, 2022), the areas in which all of these fields are relevant to a museum rather than a university need to be cautiously evaluated. These disciplines have no role in arresting the main drivers of extinctions. As recognised in the Dasgupta Review (2021), such destruction is perpetrated by economic activity. The current waves of extinctions are driven by human numbers and magnified by both poverty driving unsustainable habitat destruction, and increasing wealth driving ever increasing consumption, all of which is combined with greed, corruption and indifference. In addition, while aimed at reducing CO_2 levels, the expanding use of biofuels adds to the pace of natural habitat loss and habitat degradation (Tudge *et al*., 2021). As with any large-scale natural habitat loss this not only inevitably leads to additional extinctions but can significantly increase CO_2 emissions because of the differential extraction of CO_2 through photosynthesis between natural and transformed habitats. The International Council for Clean Transportation has shown that oil palm expansion for biofuels is a major driver of deforestation and, where it involves peat drainage, results in massive CO_2 emissions in Indonesia (Miettinen, et.al., 2012; Kharina *et al*., 2016). Biological research can help to understand but cannot resolve these issues. The greatest challenge for the NHM is more straightforward than that glimpsed in *Strategy to 2031.* It is to restore its authority and expertise in taxonomy and systematics and provide adequate staff levels to manage and develop its collections. It needs to adopt an urgent and ambitious expansion of its collections in response to the current levels of extinctions and play a leading role in developing molecular conservation collections.

From Bloomsbury to South Kensington and on to Harwell

After having outgrown their home in the British Museum in Bloomsbury, the transfer of natural history collections to the British Museum (Natural History) (BM(NH)) 'annexe' began in 1881. The neogothic splendour of the new building and its central location in South Kensington, placed among world-leading academic, artistic and cultural centres of excellence, was a measure of the stature of the undertaking. The first director (from 1884 to 1898) was William Flower, who set a standard to which directors to this day might aspire. Flower was an active researcher and innovative thinker on the role of natural history museums, the importance of research collections and the role of collections in communicating with the public. By the time of his retirement, he had set the course of BM(NH) research and public exhibitions for the next 75 years (Flower, 1898). The public galleries and research collections were integrated and designed to both celebrate nature and to educate the public about the diversity of the natural world. The public galleries displayed numerous examples of specimens but were not just dedicated to exhibitions. Research collections were stored underneath exhibition cabinets throughout the Museum.

Two world wars and national impoverishment led to decades of neglect. The Natural History Museum had, by the time it was renamed in 1992, become a backwater in need of modernisation. Power struggles ensued between Sir Neil Chalmers, the last career scientist to have been appointed as Director (from 1988 until 2004), and the Trustees, and between the demands of public engagement and of science. Sweeping changes and loss of specialist staff initiated by Neil Chalmers, who had no background in collections-based institutions, were continued under the next director. This included the expulsion of the career based scientific leadership, the establishment of a clique of empowered administrators, and the loss of cohesion between science and exhibitions. These remain largely untold stories.

The public perception of the NHM is largely of a grand building with public exhibitions, most notably of dinosaurs. When based on specimens, well-designed exhibits in public galleries of natural history museums are important, inspiring and powerfully distinct contributions to public engagement with the natural world. However, unlike in the nineteenth century, museums are now a relatively small part of such engagement with the natural world and there are many alternative sources of information and accessible experiences available. The NHM is devoting resources to extend its public engagement reach, most notably by developing its online profile. A clear distinction needs to be made between access to important scientific resources online and the online outreach of public engagement (Hassell *et al*., 2007). There are numerous players providing online natural history information for the general public, including specialist agencies and major media organisations such as the BBC, Eden TV and The National Geographic Society, which dwarf not only the NHM's content but also its audience. Popular, scientifically based features are crafted by journalists for the NHM with a strong bias towards positive stories. This approach no doubt delights the NHM's government sponsoring department, the Department for Digital, Culture, Media & Sport (DCMS) but is it what the NHM should be doing? Largely without the NHM's 'good news' agenda, these same stories are widely available online in the media, including newspapers. It is yet another example of the NHM encroaching on areas well covered by other agencies. In seeking out positive stories and downplaying the overwhelmingly negative reality of global destruction of natural environments, these present a very biased perspective. They are more an arm of propaganda, promulgating the doctrine that with good science and good policies, there is a future where both people and the planet thrive. This media profile does nothing to enhance the NHM's stature and offers nothing that is not widely disseminated elsewhere. Although NHM research activity is promoted by being woven into some of these stories, it is not focussed on the core academic function on which its stature as a voice of authority depended. The NHM must have an online presence but it needs to have clear objectives and to set limits and constraints on its ambitions. It is essential to stay within its areas of authority and niche identity. The truly important function of the museum is its role, shared with very few institutions, in holding world leading specimen collections—libraries of life—and associated scientific expertise.

With impeccably bad timing, when the scientific expertise and role of the NHM and of its collections need to be harnessed for addressing issues relating to the biodiversity crisis, the Museum is embarking on a new venture. This is the disruptive transfer and fragmentation of its scientific resources, which will result in some 40% of its collections and associated staff moving to a site at Harwell, 50 miles away. This will restrict and disrupt access to these collections for many years and fragment the institution's scientific cohesion. The origin and early development of the plan was carried out largely in secret. Early deliberations were excluded from the published records of minutes of the Trustees' meetings. Who the instigators of the move were and what their motivation was, deserves critical forensic investigation. Little of this information, however, is currently in the public domain. The chain of ignorance and incompetence driving the move to Harwell has been an unashamedly top-down campaign to remove science from the South Kensington site. 'The move would not only facilitate care for specimens but enhance their longevity and increase research potential, but also frees up areas of the Museum's estate which can be utilised by the public' (Packer, 2021). All supposed justifications for the move should be viewed in the light of freeing up areas of the Museum's estate; supposed benefits to the collections and research relative to on-site solutions at South Kensington are fiction. While there is an overwhelming case for drastically improving public exhibitions, there is no demonstrable justification for increasing public gallery space. Information on exactly how the vast areas "freed up" at South Kensington will be used is unavailable. The decision for the move to Harwell Innovation and Science Campus was finalised before any cohesive consideration was given to what collections and NHM staff would be based there. Why £180 million was awarded to the NHM for the Harwell move before any notion of what it would entail and what it would ultimately cost to fulfil, is truly a bizarre act of government extravagance (UKSPA, 2020). One thing is clear; the move to Harwell was not driven by science.

Among the spurious assertions in support of the move to Harwell is the claim that it will deliver exciting 'green' credentials, including net zero carbon (NHM, 2021a). However, in addition to the massive carbon footprint of a new building, Harwell will serve only to export high energy consumption to staff, who will either be dependent on cars for commuting and contact with South Kensington, reliant on time-consuming, inconvenient, high public transport costs and energy use, or possibly constrained to using a shuttle service. No consultation whatsoever has taken place with external stakeholders, such as regular scientific visitors, and on how the move will impact them.

One of the most productive and positive aspects of the NHM's scientific culture in the past few decades has been the educating of young scientists through PhD and postdoctoral supervision and the running of MSc programmes. At the NHM, research students can engage with London's world-leading academic societies such as the Royal Society, the Linnean Society, the Geological Society, the Royal Geographical Society and London's university colleges, together with the meeting points of numerous specialist life sciences societies. They can benefit from the world's richest assemblage of cultural resources. The NHM at South Kensington is about two hours away from Harwell using public transport and while the historic university city of Oxford has much to offer, it is about an hour away using public transport. What NHM research student would want to exchange the heart of intellectual excellence at South Kensington for the isolation of a science and technology park at Harwell that offers little common ground with the undertakings of their neighbours? If research students who are working on groups that are to be based at Harwell are stationed at South Kensington, then there is little point in their being based at the NHM at all. Indeed, with the loss of expertise in natural history and support of research irrelevant to a museum, future subjects for postgraduate research will follow this trend to areas that could be undertaken solely in universities and other research agencies.

The NHM has been desperately seeking to demonstrate the potential of synergistic interactions at Harwell. Based on a programme investigating insects, the UK's national synchrotron at Harwell has been announced as the foundation for biodiversity phenomics, the analysis of huge data sets on organisms and their interactions (Diamond Light Source, 2020). Although the synchrotron is a powerful tool for imaging 3-dimensional morphology in great detail, synchrotrons can only make a minor contribution to the broad scope of phenomics. On its own, the synchrotron is far from providing information to support the assertion that 'detailed big data on species biology is vital in enabling targeted conservation efforts to halt the devastating decline in numbers and extinction of insect species' (Diamond Light Source, 2020). Furthermore, such efforts are largely irrelevant to human-induced habitat loss and extinctions. What the synchrotron insect project does demonstrate is that proximity to Harwell is not needed for developing collaborative projects, as is clear from the fact that the insect collections will remain at South Kensington (NHM, 2021b)

The following assertion in *Strategy to 2031* (NHM, 2019, page 9), in relation to the move to Harwell, is yet another insult to intelligence:

> 'This ambition is similar to that of Richard Owen, our first Museum Director, who was determined to make the Natural History Museum the world's finest institution dedicated to natural history and who, from 1880, over three years, moved the natural history collection from the British Museum… It will be a hub for partnership with research institutions, museums and industry'.

For a part of science to be packed off to Harwell is nothing of the kind and bears no comparison with the academic and cultural stature celebrated by the move to South Kensington.

However, nothing in *Strategy to 2031* is as ill-informed and potentially devastating to NHM activity as the overriding priority devoted to digitising all of the NHM's historical collections (NHM, 2019, page 10):

> A new facility will also enable us to accelerate the digitisation of our collection, as well as to work with other great museums and herbaria around the world to unite digitally over 1.5 billion items in global natural history collections so that they can be used by all. Currently, only around 5% of our collection is digitised, yet remarkably, 18 billion specimen and research records have already been downloaded, and over 400 scientific publications cite these data, demonstrating the immense potential there is for our collection to make an impact. Digitising our collection is essential for important research on a host of societal challenges, such as adapting to climate change, addressing biodiversity loss, feeding the Earth's population and using its raw materials in a sustainable way.

Just how a different location for collections can facilitate digitisation is not explained. While the downloading of eighteen billion specimen and research records may sound impressive, that just 400 scientific papers cite these data is surely a trifling number. It is certainly not a demonstration of immense potential for the NHM's collections to make an impact—this has already been achieved in numerous publications throughout the Museum's history. Unselectively digitising the remaining 95% would be an enormous burden promoted through ignorance of the nature of the historical collections and indifference to what is going on in the outside world. This is not the time for such efforts to be prioritised. The supposed value of digitising all of the NHM's collections has become entrenched as an unchallenged groupthink belief system that staff are required to espouse. External consultants have been commissioned to 'demonstrate' the financial gains in databasing life science collections that can be obtained from medical and agricultural applications, from addressing invasive species and in conservation. These are unlikely to stand up to scrutiny. Digitisation of NHM collections needs to be focussed, selective and prioritised (Godfrey and Knapp, 2004; Hassell, *et al.*, 2007). There are circumstances where extensive databasing of large collections can be justified. For example, a significant proportion of the close on 4 million land snail specimens of the devastated Hawaiian and other Pacific Island land snail faunas in the collections of the Bishop Museum (Yeung and Hayes, 2018). In contrast, databasing the NHM's entire collection may produce vast quantities of poor-quality data for certain academics to play with endlessly but do absolutely nothing towards adapting to climate change, addressing biodiversity loss and feeding the world's population. This is all part of a desperate marketing fantasy, presumably driven by the digital element in the Department for Digital, Culture, Media & Sport, that does not begin to understand how to use the information content in historical natural history collections. The current fashion for using massive sources of data for addressing global issues has very limited applications for historical natural history collections. As historical records, nineteenth century collections might be irreplaceable but, for the most part, they were assembled in random opportunistic ways, often with limited expertise, if any. They often represent casual, unsystematically accumulated, highly biased, poorly documented and frequently misidentified samples that are meaningless for ecological research. Sophisticated algorithms cannot restore information that does not exist (Nekola *et al.*, 2019). Even collections made by experts in the latter half of the twentieth century have been shown to have fewer than 80% of samples correctly identified; 5% of locality records were wrong (Nekola in litt., 9th September 2021; Nekola and Horsák, 2022). This can be attributed to the lack of time and resources devoted to the most basic foundations of biology, notably the correct identification and naming of species. Nevertheless, the fact that these collections exist and can be studied and evaluated indefinitely means that their resource value exists for future generations and, apart from physical degradation and loss of data, is not generally constrained by how they have been used in the past. Information content fixed by databasing will have no lasting value and routine yet time consuming updating of records cannot be managed or justified for much of the material.

It is essential to have computerised systems for the retrieval of molecular collections and important to make computerised records of new acquisitions and significant historical material, notably type series, but historical morphological collections as a whole are a different matter. These are arranged systematically so that specimens and their near relatives can be conveniently accessed; they therefore constitute their own physical retrieval system. There is every chance that a sample may not have been examined and evaluated for 150 years or more. If the geographical data with historical material was sufficiently precise, this in itself would be of value. Although any geographical information is of some value, few historical locality records are precise. Even in the relatively infrequent cases of specific locality records, interpreting historical place names often requires specialised knowledge and time-consuming investigation (*e.g.* Raheem *et al.*, 2014; Sutcharit *et al.*, 2019; Preece *et al.*, in press). Blindly entering data and identifications made 150 years ago ossifies concepts and practices as does entering the historical label information into a database without time consuming interpretation and evaluation. It is at best of transient and minimal value. Even specimen images have very limited use for most of this material. It is the curators' input and interactions with other researchers that can provide scientific value to historical collections. Detailed examination of the collections to gain understanding of variation within and between species, and revising their taxonomic status in research papers and monographs, are among the proven ways in which historical collections have value as physical entities, not as meaningless sets of data.

The decision to relocate has been followed up by consultation exercises that appear to have been structured and manipulated to gain endorsement for decisions that have already been made. The perception of many curators is that unnecessarily large sums have been spent on external consultants as a tool to drive an agenda by 'consultocracy' and also absolve the Museum's management of accountability (Ylönen and Kuusela, 2019). Curators are concerned that consultants and contracted staff are making executive decisions for which they have no expertise and that extravagant and ill-informed claims and marketing of the Harwell project are being pursued, both internally and externally. A new permanent post of Director of Policy to drive *Strategy to 2031* was advertised (*Guardian*, 2021), which described the NHM's 'Industry' as 'Arts & heritage, Heritage, Museums & galleries, Venue, Charities, Arts & culture, Community development, Policy & research, Social welfare'. This summary unequivocally encapsulates how completely inappropriate DCMS is as a government sponsoring department for a world-leading collections-based research institution for the natural world.

Simply moving specimens from South Kensington to Harwell using specialist contractors will cost many millions of pounds. At eye watering costs that have yet to be determined, half of the currently stored 11 million alcohol preserved specimens in the excellent new storage in Phase One of the Darwin Centre at South Kensington since 2001, are scheduled to be moved to newly constructed facilities at Harwell. Numerous new temporary appointments for the Harwell move are in prospect, very few of which are likely to lead to meaningful permanent appointments of curatorial staff with taxonomic expertise. Curators have no confidence that funds will be sufficient to cover even the initial costs of delivering the Harwell project, let alone the significant additional long-term running costs inherent in sustaining an integrated research and collections organisation on remote sites.

Whereas the NHM owns its prime location in South Kensington and the sites at Tring and Wandsworth, the site in Harwell will be leased from a campus in which Brookfield Asset Management holds a 50% stake through its Strategic Real Estate Partners III Fund (FieldHouse Associates, 2020). There are fears that the grandiose ambitions for Harwell cannot be met and that drastic cost cutting will cause permanent damage to collections, the provision of support facilities and the long-term affordability of essential scientific staff. With the continuing divergence from an integrated museum of science and education into the separate entities of Disneyland-inspired public exhibitions and academic science, there is a case for formalising the distinction and creating two independent institutions (Gee, 1990). However, the current dismemberment of NHM science and loss of expertise is a self-inflicted pathway to disintegration with no end objective having been identified. Kicking out some half of science while holding onto the rest at South Kensington is not a coherent or defensible strategy for science. The move to Harwell is presented as offering exciting new opportunities. It does not. In reality it was an appalling decision that scientists were powerless to prevent; it inflicts a considerable, costly and entirely unnecessary permanent burden on the NHM that will mutilate its scientific cultural identity and function.

Update

Over two years since announcing the move to Harwell and having failed to reach agreement on a lease with Brookfield Asset Management, the move to Harwell has been abandoned. When this became apparent was not disclosed to staff, who were obliged to concentrate efforts on a move to Harwell. An information embargo was in place until an alternative site was finalised.

Subject to the granting of planning permission for a new building, the new location is Thames Valley Science Park at Shinfield, Berkshire, which is owned by the University of Reading. A shorter distance than to Harwell, travel from central London to Reading will also be speedier and easier when the new Elizabeth Line is fully operational. However, with a return peak time fare from London to Reading projected to be £48.80 the cost is significant. The main entrance to the large sprawling Reading University campus is about 20 minutes away from Shinfield by bus. Rather than simply being an out of London relocation, as was promoted for Harwell, the emphasis now is on collaboration with the University of Reading. On 20th May 2022 the NHM issued a press statement (NHM, 2022) setting out the fait accompli of a new location formally approved by NHM Trustees and DCMS:

> 'a new global and sustainable base for high-end natural sciences research and international collaboration with the University of Reading'.
>
> 'It will widen access to the collections for the Museum's 350 scientists, their collaborators, and researchers worldwide through rapid digitisation and cutting edge facilities'…. 'It will help ensure the collections and the vast data contained in them are safe, accessible and digitally available for researchers all over the world, strengthening the UK's position in finding solutions to the planetary emergency'.

Statement from Arts minister Lord Parkinson:

> 'This fantastic project to protect the Natural History Museum collection for future generations and to help academics and researchers tackle major challenges such as climate change, food security and biodiversity conservation'.

Statement of the Director of the Natural History Museum Doug Gurr:

> 'The University of Reading has a world-class reputation for teaching and research and there is enormous scope for collaboration on shared areas of scientific specialisms from climate science to agriculture and forestry, biodiversity loss and emerging diseases.
>
> We look forward to joining the lively community of ambitious, knowledge-based organisations at Thames

> Valley Science Park and forging closer relationships with institutions already based there—and of course reuniting with the British Museum through its Archaeological Research Collection'.

That an arts minister is called on to make a statement on the future of a leading UK scientific institution reveals much about the Government's perception of science and how totally inappropriate DCMS is as a government sponsoring body for the Museum.

Natural history collections are physical entities that need to be examined; separating some half of the collections (depending on how they are measured) and the 350 scientists to different locations does not widen access to staff or researchers worldwide. Digitising the outstanding 95% of collections has many problems associated with it as discussed above; it is an ill-informed and distorted notion of priorities in the context of a planetary emergency. The UK's position in finding solutions to the planetary emergency needs to be grounded on engagement with the real world, not in a virtual world of big data analyses.

Climate change science is clearly of critical importance but the NHM's role should be focussed on how its collections can contribute; agriculture, forestry, and emerging diseases are not core NHM subjects rooted in collections-based research or the biodiversity crisis. This exemplifies how the NHM is being driven to an agenda irrelevant to the planetary emergency and well served by other agencies.

The issue of collaboration with the University of Reading (QS World University Ranking 202), raises a number of questions. Imperial College (QS World Ranking 7) is next door to the NHM South Kensington, University College (QS World Ranking 8) and Kings College London (QS World Ranking 35) are a few stops on the London Underground. There are numerous other outstanding educational and research institutions in London. Why does the NHM need to seek collaboration with the University of Reading in particular? What does a collections storage outstation of the British Museum's Archaeological Research Collection, designed for accommodating few visitors, offer that the BM Bloomsbury does not (British Museum, 2022)? If there is substantial common ground with the BM in addressing a planetary emergency, what is it and why has it not been acted on?

The NHM needs to reflect on its intrinsic value as an institution. A robust and identifiable institutional base and a shared identity are important for engaging with the wider world. For NHM life sciences in particular, this means working globally, focussing geographically on centres of threatened biodiversity. Being part of and backed by a cohesive institution of international stature is fundamental to the success of such ventures. A divided, dissipated institution will be permanently and increasingly emasculated.

A great deal is learned by interacting with immediate colleagues and colleagues within an institution. However, informal interactions and seminars given by staff and visitors are not enhanced by being divided at different locations. Furthermore, and valuable as they are, such interactions may not develop into collaboration; fruitful collaboration cannot be mandated on the basis of proximity. Breaking up the NHM and fostering collaboration based on the convenience of local proximity for one NHM group is a pathway to institutional degradation. Collaboration should be determined by shared interests and shared purpose, by reaching out to colleagues both nationally and internationally and attracting research students from around the world. One-sided, hard-sale marketing efforts that support the dismemberment of a cherished institution of international stature, cannot disguise the fact that none of this ill-conceived and unfolding disaster makes sense. The press release exposes with glaring clarity the lack of coherent thinking behind the breakup of the NHM and government incompetence in dealing with a scientific institution. Resetting of the clock on a move must now give rise to hope that this foolhardy venture can be stopped.

How did the Natural History Museum lose its way?

A detailed analysis of the history of the NHM, and the culpability of key players that led to *Strategy to 2031* will be given elsewhere (Naggs, in manuscript). However, it is clear that the ethos of the NHM has been transformed and degraded by an utterly inappropriate leadership and funding model. This originates from government action. The NHM is the only Public Sector Research Establishment to be funded through the Department for Digital, Culture, Media & Sport. This role of DCMS has been an unmitigated disaster. DCMS is exactly what it says; it is not driven by science and the study of the natural world, but by 'digitisation', by human achievements—in the arts and sport, and dissemination of information through the media. Some areas of the 'museum sector' might be suitably nurtured by DCMS, but the NHM's scientific remit most certainly is not. The culture that it propagates has permeated the NHM's power structure from the Trustees and senior management down to the most junior staff. What expertise and authority on the role of a major collections-based research institution the majority of the NHM's Trustees, the Director and the Executive Board bring is obscure (NHM, 2021c). Science formerly had a powerful voice at the NHM. The Director and Deputy Director were scientists experienced in collections-based research and were often recognised as international authorities in their scientific fields. The next tier of management was the heads of the long-established scientific departments, known as Keepers of the Collections. The Keepers were influential heads of the Zoology, Entomology, Palaeontology, Botany and Mineralogy departments. This whole structure of scientific stature was swept away, the departments were first shrunk to Life and Earth Sciences before being diminished into the 'Science Group'. To the very limited extent that science still has an executive voice at the NHM, it is merely supplicant and compliant with the DCMS agenda. If DCMS has an interest in the natural world it is entirely anthropocentric, concerned only with how humankind benefits from biodiversity as a resource and how it relates to human health. This is reflected in NHM objectives—'delivering impact in areas of public and industrial need' (NHM, 2021b). Clearly, government funding of science must include support of endeavours to improve economic wellbeing and to make medical and agricultural advances, but such undertakings should only be peripheral to the NHM's responsibility for engaging with priority issues in the natural world. The UK Government recognises that there are priority areas beyond immediate human benefit (UK Government 2020); recording, understanding and saving living diversity must surely be a significant issue of our lifetime. The NHM asserts that 'As well as reaching out to public audiences, the Museum will increase its sphere of influence at home and abroad to inform actions and policy in business and in government, at a local and international level' (NHM, 2020c). However, it is difficult to see where such authority will come from.

The drive to secure external funding has transferred much of the NHM's agenda into the hands of funding agencies rather than being set by NHM priorities. The approach is not to identify what the NHM should be doing and only then to consider how it might be funded. It is the opposite: what funding is available and what do we need to do to secure it? This rewards a culture that is not concerned with NHM objectives and ultimately leads to redirection of the NHM towards serving outside interests. Rather than life sciences being able to respond to the biodiversity crisis, they are being directed into applied fields such as medical and agricultural research that are best provided for elsewhere, without undermining NHM science. The core NHM activities in collections-based biodiversity render a priceless service to the whole of humankind and the planet. These activities warrant full financial support from government.

How has this been allowed to happen? In the space of a few decades, a succession of scientists who had managed the NHM as an integrated organisation since its origins at South Kensington, were replaced by a clique of career managers. A well-informed non-scientist with a proven commitment to the natural world could be an effective if largely symbolic leader but the reins of power have been usurped by executive directors who lack the knowledge, competence, understanding or vision to lead. In signing up to *Strategy to 2031*, in ticking a long list of institutionally irrelevant DCMS priority boxes and losing sight of NHM core functions, this corporate hierarchy has rapidly transformed the NHM into a meaningless all-embracing agency with vacuous aspirations to 'save the planet'. Aspiring to lead in a whole range of diverse global issues serves only to demonstrate the degree to which the NHM lacks institutional identity, academic integrity, competent leadership and understanding of its capabilities, strengths and obligations. The powerful and unique roles that justify the NHM's existence and which have the potential to be developed in critically important new directions, have been undermined. That the current NHM leadership clearly has no belief in or understanding of the overriding importance of its core function, no ability to have clearly focussed and relevant objectives or any recognition that its time has come, is truly shameful.

Concern about the loss of expertise at the NHM and the shift away from a focus on biological taxonomy and systematics has been expressed over many years, particularly following the changes introduced by the then director Neil Chalmers over 30 years ago (Gingerich, 1990; Joysey *et al*., 1990; Bourne, 1990; Erzinçlioglu, 1993). However, the on-going and more profound changes of recent years appear to have accumulated under the radar of outside agencies such as university academics, environmental groups, specialist societies and the media. Hopefully, they will wake up to the direction being taken by the NHM, and demand action. The real stakeholders—future generations—do not yet have a voice, but the NHM will ultimately be accountable to them for its failings.

Researchers and Curators

Most scientific staff at the NHM are currently classed as either curators or researchers. Curators are primarily responsible for management of the collections and researchers for undertaking and publishing research. The distinction between their activities is blurred in that most curators also pursue and publish research to varying degrees and, until recently, researchers contributed to documenting and organising collections. However, from integrated teams of researchers and curators specialising in particular taxonomic groups, separate and divisive line-management structures were imposed. In the past, scientists' work was integrated into research and collections-based activity and a key role in life sciences was in their becoming world-leading authorities on broad groups of organisms, such as phyla of animals, as well as highly specialised experts within particular groups of organisms. They were also very knowledgeable of the nature and scope of the collections. The scientific authority of the NHM was based on such expertise. The rapid loss of such expertise is not simply a wilful lack of succession planning; it is an active policy that does not value such expertise either in retaining existing staff or in making new appointments. From a time when it was accepted that NHM research must be collections based, that if it could be conducted in a university then it did not belong in the NHM, detailed knowledge of living diversity is now being purposefully obliterated and such scientific authority demolished.

Outstanding, prestigious and important research areas in applied fields of parasitology have been developed at the NHM (*e.g.* Rollinson *et al*., 2013; Waeschenbach *et al*., 2017; Ásbjörnsdóttir *et al*., 2018; Papaiakovou *et al*., 2019, 2021). However, as with other research areas that may be excellent but do not relate to systematics (*e.g.*, Williams *et al.*, 2016, Williams, 2017), they do not develop traditional expertise in biodiversity appropriate for a collections-based institution that is relevant to the biodiversity crisis—the global emergency. The high-profile work of the Diversity and Informatics Division (*e.g.*, Purvis *et al*., 2018) addresses important biodiversity issues that generate considerable attention. However, such modelling work does not engage with the NHM collections significantly or contribute to expertise in taxonomic groups. If any of this research activity were conducted on a small-scale relative to a dynamic research profile in biological taxonomy and systematics, it might be thought of as stimulating the NHM's scope of scientific engagement. However, while such research is flourishing, expertise in biodiversity represented by employed staff has been eliminated. For example, fish that represent almost half of all vertebrate groups combined, had a flourishing team in the Fish Section when I joined the Museum in 1974. In addition to two assistants dedicated to the care of the collections, there were ten researchers and research assistants with varying responsibilities to research and curation; all were employed fulltime. There were also two associate researchers. The Fish Section had a prodigious publication output and was recognised as arguably the world's leading fish research group in systematics. There are now no fish researchers in what was the Zoology Department and just two overwhelmed curators who are responsible for the collections. With four researchers and four curators, the NHM Mollusca Group was recognised as the leading research group in molluscan systematics in the world. There are now no dedicated researchers employed in molluscan systematics and just two full time curators and one part time to deal with an estimated 8 million specimens, ranging in size from Giant Squid to microscopic snails. Many of the collection areas in life sciences now have no curators dedicated to them and they are covered by a skeleton staff.

The contrast with the NHM's position up until a decade ago is striking. Beginning in the 1990s, it was correctly recognised that the demographic profile of systematists and taxonomists was that of an aging population with inadequate recruitment from the coming generation. Their expertise was recognised as a foundation for all life sciences. The NHM was at the forefront of highlighting the problem and provided evidence to three House of Lords Science and Technology Committee investigations on systematics and taxonomy in 1992, 2001–2002 and 2007–2008. The House of Lords final report (Parliament UK, 2008, Abstract and page 7) concluded (recommendation 6.20) that a problem for taxonomy and systematics lay with the Government not having placed taxonomy and systematics within a scientific department. In considering that 'a discipline may benefit from its interaction with a number of departments, all of which have an interest in its activities', the Government rejected this recommendation (Parliament UK, 2009). The Committee countered that it had taken the view that in this particular instance there were reasons why this diffuse approach was not working in the best interests of the health of the discipline. It is clear from this that culpability for much of the demise of taxonomy and systematics in the NHM demonstrably lies directly with anonymous government decisions. It is conspicuous in this context that the political establishment in the UK is scientifically illiterate: notably, not one of the UK's 650 members of parliament holds a degree in a biological subject (Goulson, 2021).

The shortage of trained systematists and taxonomists used to be referred to as the taxonomic impediment. However, despite university courses coming to shun systematics (Britz, *et al.*, 2020), there was no shortage of expertise in the pool of postgraduate researchers that could be developed into careers in systematics. The true impediment was simply the diminishing number of people being employed in the field in the UK. This, despite all their proclamations, was increasingly the case in the NHM itself. Although an institutional change to encourage supervision of PhD students and short-term postdoctoral researcher contracts greatly benefitted NHM research, impact and dynamism, the NHM did not offer careers to the most precious commodity it possessed. After years of developing their expertise and career potential, outstanding NHM-trained systematists went to waste or went abroad. In addition to the wasted years of developing expertise undertaken by research students can be added the years of commitment and dedication provided by their supervisors. With the transformation in subject matter of NHM researchers, the subjects pursued by postgraduate research students will inevitably follow this trend. A previously major employer of research systematists in Britain, it seems scarcely creditable but, rather than arresting the loss of systematists in the UK, under government influence, the NHM is largely responsible for their demise. Nevertheless, with well-practised doublespeak, the NHM continues to assert that taxonomy and systematics are at the heart of what it undertakes. Those researchers in life sciences who do not fit the profile of being authorities on groups of organisms and whose research is not intimately linked with the collections—and these are now in the majority—should simply have no place in the NHM. One test of this might be those researchers who do not move to Reading when the collections related to their work move there.

As with any information-based field of endeavour, biological taxonomy and systematics are undergoing rapid change. While new molecular tools such as DNA bar coding can be developed and accessed by both taxonomists and systematists and by biologists in general, this does not reduce the need for taxonomic expertise as some such as Godfray (2007) and Miller (2007) have argued. The fundamental need to be able to have access to reliable identifications and reliable nomenclature applies now as much as it has since the binomial system of nomenclature was introduced by Carl Linnaeus in 1758. This provided a practical means for naming and facilitating the classification of life. As expertise in interpreting historical material is lost, three hundred years of accumulated knowledge is neglected. Knowledge of phenotypic characters of organisms and their link to taxon delimitation is insufficiently valued and is being lost. Notably, the most valued historical 'type' specimens, from which species were originally described, are being routinely bypassed, as both reference points for attributing names and, when recognised as biological species, what such species are. Misidentified molecular material and sequence data are often used as reference sources from which subsequent incorrect identifications are made.

Taxonomists and systematists are needed more than ever before, including to relate formally recognised species to molecular data. Two notable successes of international collaboration in bioinformatics are MolluscaBase (2022) and WoRMS (WoRMS, 2022; Costello *et al*., 2018). MolluscaBase provides an authoritative, continuously updated database of the nomenclature of all recognised molluscan species, the second largest animal phylum after arthropods; WoRMS is a World register of marine species. However, identifying material continues to be dependent on experience and skill in interpreting phenotypes. Having reliably identified material in international genetic sequence databases is essential but lacking.

In developing methodologies, expertise and research facilities for whole genome sequencing, the ground breaking success of the Human Genome Project in 2003 established a capacity for extending whole genome sequencing in the animal kingdom. The international Genome 10K (G10K) consortium has worked over a five-year period to evaluate and reduce the cost of methods for assembling highly accurate and nearly complete reference genomes. To date, genomes of only 16 species have been assembled by the G10 Consortium, representing six major vertebrate lineages. However, Hotaling *et al*., (2021) identified genome assemblies in GenBank for more than 3,200 metazoan species in 24 phyla. Work has embarked on the Vertebrate Genomes Project (VGP) to complete reference genomes for all of the roughly 70,000 currently recognised extant vertebrate species and to help to 'enable a new era of discovery across the life sciences' (Rhie *et al*., 2021). The NHM supports this grandiose, highly acclaimed, high status 'Big Science' initiative which, however, remains enormously expensive and extremely time consuming. The considerable advances in sequencing methodologies will doubtless allow an acceleration of the programme. This is an impressive undertaking of considerable academic interest that will provide an enormous amount of genome data and be invaluable for recording and understanding the evolution of life. However, beyond technical developments, five critically important issues need to be answered. Where is the expertise for providing accurate identifications of voucher samples? How does whole genome sequencing have direct relevance to the touted fundamental application for species conservation under the current drivers of extinctions? To what extent can this ambitious programme be conducted internationally in the context of bio-nationalism and the bureaucratic swamp of endless CBD deliberations (e.g., CBD, 2021)? How relevant is this exercise when vertebrates represent less than 1% of multicellular animal eucaryotes and, if the planetary emergency is of overriding priority, how can the resources and massive expenditure of this programme be justified in the context of the current scale of extinctions? If whole genome sequencing programmes could embrace the preservation of cell lines it would transform their relevance.

However, in the absence of relevant expertise, the extent to which the international genetic sequence database GenBank (2021), the Earth BioGenome Project, the Darwin Tree of Life project and bar-coded species have been wrongly identified is undoubtedly very high (Smith *et al*., 2016). A critical review of insects in GenBank showed a degree of accuracy of about 50% (Meiklejohn *et al*., 2019). Furthermore, in the absence of a disciplined system of museum-based voucher samples, verification of identifications is impossible for probably the majority of sequence records. The NHM has not only been silent on this but in participating in such projects while having disposed of much of its expertise, is culpably acquiescent. With a major extinction event underway, the notion that experts in taxonomy and systematics can be dispensed with is bizarre. Nevertheless, robust recognition of the importance of taxonomists and systematists has not arrested their loss; an inexplicable tragedy that is not confined to the NHM (Disney, 1998; Agnarsson and Kuntner, 2007; de Carvalho *et al*., 2007; Britz *et al*., 2020; Wheeler, 2014, 2020).

Academic safeguards and accountability

Publicly funded institutions need to be accountable for what they do and a routine process to achieve oversight of the relevance and quality in scientific institutions is for their endeavours to be subject to scrutiny by external academic peers. The direction that NHM science followed was subject to regular reviews by external teams of academics known as visiting groups. Committees can be selectively structured to push through agendas but it is difficult to see how an independent group of relevant academics of any stature could endorse the current direction of the NHM. This is presumably why no one's opinions have been sought for the past 16 years and the practice of visiting groups apparently abandoned. The last visiting group (VG) to the Department of Zoology (now subsumed into 'Science Group') was in 2006. Chaired by Professor Michael Hassel, who was then a Trustee at the NHM, the VG provided a powerful report (Hassel, *et al*., 2007). A number of observations and recommendations were made that are completely at odds with the subsequent direction taken by the NHM. The VG recognised the NHM's unique value in taxonomy and systematics as an essential world-class resource underpinning the biological sciences, and its increasing importance in addressing global concerns in biodiversity. However, the VG also expressed concern about a trend towards the irrelevance of some research in the context of the Museum and a lack of connection with the collections. The NHM has since travelled a long way down this road of neglecting the collections, taxonomy and systematics in its research. The VG particularly articulated strong reservations about the loss of expertise in taxonomy and systematics in both the schistosome and parasitic worm groups. They cautioned against allowing research activities in these groups becoming inappropriate for museum research and extending beyond the Museum's remit into conventional biomedical research. Nevertheless, this is exactly what has happened.

Applied fields of research

Instead of focussing on biodiversity, the NHM continues to enter and develop areas of medical and agricultural research that are neither its strength or even its business. Projects in such fields are celebrated because they can be generously funded; they are lauded as being relevant to human wellbeing and therefore must be good and desirable. Applied medical research within the NHM, notably in areas of parasitology, has been rapidly expanding over the years and PhD supervision is being actively pursued as part of the UK Food Systems Centre for Doctoral Training (UKFS-CDT, 2022). For example, the NHM has expressed interest in pursuing projects addressing questions such as cooking fats and their relationship with ethnicity; how much should your coffee cost? and how does the UK cook? Worthy as these pursuits may or may not be, they can be well served by numerous other agencies and research establishments and are utterly inappropriate for any natural history museum. It should be noted that nearly all funding for agricultural research now comes from the major agrochemical industries. Government support was progressively withdrawn from numerous experimental farms that were set up in a period starting 75 years ago to research best practices in farming. The Agricultural Development Advisory Service, originally government funded, was privatised in 1997 and is now a commercial business (Goulson, 2021).

The NHM's collections can facilitate many areas of both applied and purely academic research. Indeed, the provision of access to such resources is an important role for the NHM. Where such applied research calls upon expertise in biological taxonomy and systematics it is absolutely relevant to the NHM. Examples of such research include the Barcoding Facility for Organisms and Tissues of Policy Concern that provides identifications on traditional morphology-based approaches requiring taxonomic expertise and/or DNA-based techniques (BopCo n.d; Dimzas *et al*., 2020; Gombeer *et al*., 2021; Smitz, 2021). BopCo is jointly run by the Royal Belgian Institute of Natural Sciences (RBINS) and the Royal Museum for Central Africa (RMCA), and is part of the Belgian federal contribution of the Belgian Science Policy Office (Belspo) to the European Research Infrastructure Consortium LifeWatch.

However, the NHM should not be drawn into a primary role in applied fields of research. Of course, the current NHM ethos asserts that such fields of endeavour are its business now, and this is at the heart of the problem. For example, Heath (2018, pages 16-17) noted that in 2015 a NHM project was funded by the Bill and Melinda Gates Foundation to look into intestinal parasitic worms and their transmission through soil. This project was considered by Heath to be a 'pet project' of a particular scientist that was appropriate for a university or medical research agency, but was irrelevant to the role of the NHM. The scientist concerned is now the Director of Science.

Rewilding

Strategy to 2031 begins by invoking the considerable authority of Sir David Attenborough: "*The future of the natural world, on which we all depend, is in your hands*." However, the NHM does not follow up by acting on the only path for the long-term future of biodiversity that Sir David advocates. After a lifetime of exploring, celebrating and ultimately recognising the rapid rate of extinction of living diversity, Sir David accepts that the only hope for retaining a biodiverse world is the restoration of habitats and the reintroduction of diverse biotas, a process widely known as rewilding (Attenborough and Hughes, 2020). In the long term, such rewilding is the only mechanism that can save a significant proportion of non-marine biological diversity. However, rewilding requires a reservoir of biological diversity to seed restored habitats. Contrary to Attenborough and Hughes' (2020) suggestion that ameliorating actions in the immediate future can turn the tide on extinctions, such actions can do no more than marginally mitigate the threats driving extinctions. We must look to a far longer timescale for turning the situation around, after human pressure on resources has significantly declined. Contemporary rewilding is often controversial, despite involving few species and having limited ambition. Global rewilding as a means of restoring diversity in the more distant future is a very different concept—a far more important, ambitious, essential and urgent undertaking.

Conservation, biobanking and cryogenic reproductive strategies

Through captive breeding and the development of cryogenic reproductive science, leading zoological gardens are playing an important role in conserving a few, mainly iconic species (Ryder and Onuma, 2018). This field is led by the Frozen Zoo in San Diego (2021) and is being pursued by the Center for Species Survival's Genome Resource Bank at the Smithsonian's National Zoo and Conservation Biology Institute (SCBI, 2022). In Britain, the Frozen Ark (Clarke, 2009; Breithoff and Harrison, 2018; Frozen Ark, 2021) and recently Nature's SAFE (2021) recognise the desperate need for preserving living cells in order to conserve animal species. Assisted reproductive technologies such as supplementing captive-bred populations with biobanked founder sperm, promises to be of value for retaining genetic diversity in threatened species (Howell, *et al.*, 2021). It is important to be clear that these approaches have nothing to do with restoring extinct species but in saving living species from extinction. Much valuable research in animal biobanking and cloning is undertaken by commercial agencies such as Gemini Genetics (2021) in England and Viagen (2021) in the USA, which are primarily involved with cloning pets and horses. However, none of these initiatives can operate in a manner or on a scale that is appropriate to the magnitude of global biodiversity loss. Animal conservation as a whole is beyond the reach of zoos and pet cloning agencies.

However, collections of living plants in botanic gardens do make a major contribution to plant conservation (Botanic Gardens Conservation International, 2021). The Royal Botanic Gardens, Kew (2021), which is sponsored by the Department for Environment Food & Rural Affairs (DEFRA), has taken a proactive lead for plants with the Millennium Seed Bank at Wakehurst in Sussex and is leading the way in recognising that this needs to be extended by exploiting methods of cryopreservation (Harrison, 2017; Bargues, 2019). Cryopreservation and plant cloning are likely to be essential approaches for many tropical rainforest plants for which storage of dried seeds has been problematic. Such critically important programmes deserve to be generously underwritten with long-term government funding and international support.

The need for tissue/cell collections for molecular research, if not for conservation purposes, is acknowledged in *Strategy to 2031*, but not embraced; it is just one more ticked box without a commitment to deliver on an appropriate scale or in an appropriate direction. The NHM should both lead on the scale of its collections and be at the cutting edge of specimen preservation. In addition to adopting a range of optimal methods for preserving morphological material, field samples should be preserved as cryogenic tissue samples of living cell lines, as was pioneered for the NHM in 2013 (Naggs, 2017). This opens the door to developing cryogenic reproductive science (Ryder and Onuma, 2018). So far there has been little additional effort at the NHM beyond current preservation requirements for immediate research. However, NHM collections can and surely must act as storehouse of living diversity that will lead the world in harnessing molecular methods for conserving species and for conserving genetic diversity within species (Mackenzie-Dodds, 2022). This must be pursued on the basis of international collaboration that recognises that for securing future biodiversity as safely as possible, such cell lines must be duplicated in centres around the world, with commitments to long-term storage. We do not know how far into the future it might be before substantial restoration of habitats might be achievable but cell lines and embryos can theoretically be stored indefinitely without deterioration (Ryan, 2004; Ryder and Onuma, 2018; Lin *et al*., 2021). What we can be sure of is that, if we do not act now, future generations will be denied these options and possibilities. Development of cryogenic collections and related reproductive science is still in its infancy, but if the NHM is to be of any relevance and to have a future role as a collections-based institution, it must take a leading part in this rapidly developing field without delay.

Can the NHM recover? Summary and conclusions

- With a significant proportion of living diversity disappearing in a short time frame, what the Natural History Museum does has never been more important. It has clear and urgent responsibilities to act with honesty and relevance in public communication and to deliver on scientific obligations commensurate with its leading role as a collections-based research institution. It has unprecedented opportunities to lead in species conservation efforts. However, its current strategy, vision and priorities are fundamentally flawed and it is set on a course that can only lead to irrelevance and failure. This cannot be allowed to happen.
- There can be no doubt that the NHM needed to change, move on from its largely Victorian heritage and engage with the world of today. One of the biggest challenges is how the priceless legacies of its historical collections should be utilised and prioritised in the context of current biological realities. If the biological world was stable and not disappearing at an alarming rate, it might have been acceptable to indulge in pondering over the seductive fascination of past collections. But biodiversity is disappearing. There is an urgent need to build new collections both for future research and to contribute to safeguarding and restoring a biodiverse world.
- The reason for the NHM's very existence is being undermined and it is aiming to pursue activity in crowded fields without fulfilling its core functions. It has lost clarity of purpose and belief in its collections-based mission. This is an inevitable consequence of setting priorities driven by ease of funding and ticking all of the boxes in applied environmental, agricultural and medical research. The tragedy is that there has never been a greater need for a collections-based institution in the life sciences to harness scientific advances.
- When the NHM should have entered the twenty-first century as a science-led organization, it finds itself managed by a corporate clique incapable of recognizing what the Museum can and should be doing. Under the painfully unsuitable hegemony of DCMS, the largely inappropriate Trustees vested with considerable power, a director and executive depleted of scientific stature, authority and independence, the NHM has delivered an acutely embarrassing plan. All of the marketing efforts put into *Strategy to 2031* cannot triumph over its utterly flawed substance. The upbeat assertion that we can deal with the environmental and biodiversity crisis, and dismissive rejection of so-called doom-mongering, is not just irresponsible and dishonest, but deluded and dangerous.
- The mosaic of increasingly isolated and fragmented natural habitats in human-transformed landscapes, combined with climate change, will precipitate a cascade of extinctions in terrestrial ecosystems. Even if climate change could be brought under control, there is no prospect of this happening soon enough to prevent significant environmental impacts, and the pace of natural habitat loss and extinctions is continuing unabated. This is solely due to human numbers, human consumption and human indifference. The NHM should say so unequivocally and address the consequences.
- The consequences for the NHM are that it must

recognize that the extent and pace of extinctions demand that it returns to a collections-based focus. It should acknowledge that it now has the capacity to be at the forefront of molecular-based conservation, which is the only possible means of conserving species on an appropriate scale. With such capabilities come responsibilities. Existing collections do not begin to meet the need for a collection's legacy for a future in which much of Earth's biodiversity will have been lost.

- The NHM model of just taking what is wanted - with essential permits but without engaging in a collaborative relationship with a host country, is resonant of the mindset from colonial times; this is simply not good enough. A new model for building collections, based on shared objectives, is urgently needed in order for the NHM to retain its leading role as a collections-based institution. To date the NHM has proved to be inept in dealing with the need to work closely with biodiversity-rich countries. This has to change.
- The first step is to recognize the clear priorities and obligations of a collections-based research organization in the context of a major extinction episode. Whatever the NHM undertakes has to be funded, but there is no point in pursuing research that competes directly with universities, and medical and agricultural research institutes. The NHM needs to complement and collaborate with such agencies, without encroaching into their activities.
- A more focused NHM must channel its efforts unequivocally into its collections and collections-based research. This needs to be science-led. My own programs have demonstrated the potential for funding new collections from a wide range of sources, including funding achieved jointly with host countries. The fear of making a case for the NHM's own funding needs, rather than responding to funding priorities set by outside agencies, needs to be overcome. A new agenda does not have to be delivered overnight, it can be progressively, if urgently, developed. Major funding does not need to be in place before significant progress can be made.
- An external review body made up of scientists including leading international authorities with expertise in biodiversity and who are stakeholders in the NHM's collections, would be a first step to resetting the NHM's direction. This would need to be followed up by the restoration of regular external reviews. A complete revamping of the NHM organization and management is desperately needed but, in the meantime, the incumbents must be taken to task and directed to a new agenda.
- Given that the NHM's Executive Board is entirely dominated by non-scientific executives—those that have not pursued careers as academics in natural science collections or have no background at all in natural science—they are not competent to make scientific appointments. The NHM's senior scientific appointment panels should include independent external members—practicing scientists with expertise relevant to collections-based research and with overriding decision-making authority.
- If the NHM cannot engage appropriately with the fact that living diversity is disappearing, then it might as well not exist.

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