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Museums, Collections and Biodiversity Inventories

Pere Alberch

Natural history museums area at a turning point in their history. To play a central role in research on biodiversity, they must change their mode of operation and public image. Collections have grown in a haphazard manner, depending on the interests and preferences of successive curators. There is an urgent need to create international networks and standard practices among museums, to meet the challenge of the biodiversity crisis.

Recent years have witnessed an increased awareness on the part of the media and the general public that we live on a planet that is a relative unknown to us. Current estimates suggest that the 1.4–1.8 million species of living organisms described by scientists represent less than 15% of the actual number[1,2].

This surprising fact has found its echo among politicians, who at the 'Earth Summit', held in 1992 in Rio de Janeiro, introduced (under the auspices of the United Nations) the 'Convention on Biological Diversity', which is currently in the process of being endorsed by most countries. Among other issues, such as technology transfer and patent rights on biotechnological products, the Convention on Biological Diversity binds the signing parties to undertake a survey of the species of plants and animals living within the political boundaries of the country as well as setting aside enough protected areas to allow the preservation and sustainable use of their national flora and fauna.

This is a lofty and commendable goal and it is very positive that politicians have realized the potential economic importance attached to biodiversity. A key question now is: can such an inventory of biological diversity be done within a reasonable time? Habitat destruction is occurring rapidly and, consequently, many species disappear before we know they ever existed. It has taken science, since Linnaeus, 200 years to describe 1.4–1.8 million species. Currently, description rates across all taxa are remarkably low, averaging 13 078 per year for the period 1978–1987 (Ref. 3). Stork[2] estimates, in my view quite optimistically, that it would take a minimum of 90–120 years to describe all species at present rates. Wilson[4] has suggested that it would take 25 000 taxonomist lifetimes to complete the task. In any case, the timeframe is clearly unacceptable given the urgency of the task.

Pere Alberch is at the Museo Nacional de Ciencias Naturales (CSIC), 28006 - Madrid, Spain.

In contrast with the widely accepted view that inventorying biodiversity is an urgent and deserving task, natural history museums – reservoirs of data on biological diversity as well as centers of taxonomic expertise – continue to suffer from an image problem. They are often perceived as intellectually stagnant, even anachronistic, institutions. The reasons for this misperception are mainly historical.

Descendants of the medieval Cabinets of Curiosities, natural history museums first appeared in the 18th century in most cultured capitals of Europe. At that time museums were progressive scientific institutions. As Foucault[5] persuasively argues, museum displays and collections were a reflection of a novel view of the natural world – the linnaean concept that there exists an intrinsic order in nature. In the 19th century, and particularly with the advent of the darwinian theory of evolution, museums began to miss the train of progress. How could one integrate a dynamic view of nature within the static framework of museum collections? Slowly, museums were becoming 'museums of themselves'. In the face of change, and shrinking budgets, museum curators often have become more and more self-centered and isolated from society, revelling in past splendours and on the importance of their collections (while bitterly complaining about the insensibility and ignorance of the science policymakers who deny them the necessary funding to adequately support their institutions).

Natural history museums are at a turning point in their history. They can now play a central and critical role in the development of research leading towards the understanding, conservation and sustainable use of biodiversity. To achieve this goal, however, they must radically change their mode of operation and public image, to clearly define goals, objectives and new research strategies. If museums are unable to meet the challenge, other institutions will be created *de novo* to fill the niche. The Instituto Nacional de Biodiversidad (INBio) of Costa Rica is an example of the latter (see Box 1).

I am convinced of the urgency of the task and the need to react quickly. Museums cannot be dominated by the philosophy of inward-looking curators, working leisurely on their taxa of choice all their lives. As Raven and Wilson[1] point out, 'if taxonomy is to play the role foreordained by the biodiversity crisis, its practitioners need to formulate an explicitly stated mission with a timetable and cost estimate'.

When confronted with a changing view of nature – from order to dynamics, from description of objects to elucidation of processes – museums have undergone an identity crisis that has resulted in a progressive dilution of their research objectives. Museums should remain faithful to their identity. The collections are the museum's 'soul' and *raison d'être*. Collections are also a unique research tool in comparative biology. Therefore, whatever the research strategy that a museum wishes to develop, it cannot ignore the existence of such a unique resource. Consequently, museum-based research must emphasize disciplines that have a comparative component and that make use of the collections to some degree. Biodiversity studies are at the core of such philosophy. Therefore, museums, and allied institutions such as herbaria and botanical gardens, are uniquely qualified to play a role in any multidisciplinary approach to the biodiversity crisis.

Collections

Museum people must convince our peers in other scientific disciplines that museums can carry out

21st century research – in particular, that the biological collections that are stored in museums are essential tools for research. They certainly deserve the same support and recognition as any other database of biological diversity (e.g. banks of gene sequences).

In my view, there are three interrelated reasons why natural history collections have not been properly appreciated, and consequently underfunded: (1) loose compilation criteria; (2) absence of unified data standards; and (3) failure to identify new potential users.

Natural history collections have grown in a largely haphazard manner, contingent on the personal interests and preferences of the successive curators. Therefore, data have been organized mainly to serve the interests of the collector. It is not unusual to hear zealous field biologists talking about 'their collections', even if the material has been gathered while on the museum's payroll and the collections trip sponsored by a government funding agency.

As a result, collections around the world (and this assertion includes major institutions) are not organized along the same criteria, do not share the same data standards and the information associated with most of them has not been computerized. Such factors make the information hard to retrieve and to use most effectively.

Finally, museums need to confront the fact that they are 'service providers' to an outside user community. But, who are the users? Data on biodiversity is essential for conservation and public education programs, as well as applied purposes such as 'chemical prospections' – the search for new natural products. Museums should look beyond traditional uses of the collections and organize the information associated with them accordingly. INBio in Costa Rica is an excellent example of collections being assembled to fulfil the needs of a multi-user community (see Box 1).

The need for creating networks and standardizing practices among museums, under the auspices of international funding, is underscored by the fact that the building of reference collections, such as the ones currently existing in Europe, Australia and North America, is a slow and very expensive endeavour. Therefore, these institutions are likely to remain the primary centers of information in the near future. It is advisable and cost efficient, and also a duty to developing countries, to make the information stored in the major museums readily available to researchers in distant countries through the use of modern technology.

Box 1. The INBio: A success story

The Instituto Nacional de Biodiversidad de Costa Rica (INBio) is a non-profit making public-interest organization, established in 1989 (Ref. 10). The brainchild of a molecular biologist, Rodrigo Gámez, and an ecologist, Daniel Janzen, INBio is a novel way of using a country's biodiversity for education and economic development. The first and foremost goal of the institution is to create a relatively complete inventory of Costa Rica's biodiversity within a decade. This amounts to a total of over 500 000 species of animals and plants (including fungi, viruses, bacteria, etc.).

To achieve this ambitious goal, INBio has developed a heterodox approach to the problem. The most unusual is, perhaps, the figure of the 'parataxonomist'. Parataxonomists are selected among country people (e.g. farmers, national park rangers, housewives, etc.). In general, they have a primary school level of education. They receive a six month basic training in collection and preparation of biological samples, taxonomy and park administration. They work full-time with an adequate salary, which would be low for a person with a university degree but well above salaries obtained by people with similar levels of education. The parataxonomists are stationed at biodiversity offices located in a network over the country's conserved wildlands. They spend 17 days a month in the field and seven days at INBio headquarters. There, they receive feedback and advice when they revise the collected material with the taxonomists at INBio.

The role of the parataxonomist is important in a social as well as in a scientific context. Their residence in the field allows adequate in-depth temporal and spatial surveying. Their in-job training raises their awareness of their natural surroundings. This is transmitted to their social milieu where natural diversity is suddenly perceived both as a source of curiosity and an intellectual challenge, as well as a means of obtaining a respectable source of income.

The taxonomists at INBio are university educated but, in general, do not hold a PhD degree. They are generalists rather than experts on specific taxonomic groups. They act as liaisons between the parataxonomists and the internationally based experts that identify difficult material and describe new species.

The collections (currently only plants and arthropods are being collected) that are assembled by the 'parataxonomists' are organized at INBio headquarters and the data entered into a computer. The specimen labels are bar-coded to make computerized information reading more efficient. In collaboration with companies in the field of information technology, INBio is devising software packages that would allow the ecological and taxonomic data to be integrated into land management and conservation.

INBio has actively, and aggressively, searched new uses of the information compiled. A tangible first step was achieved when it signed an agreement with the pharmaceutical company Merck. In what is probably the first joint venture between a multinational biotechnology company and a country that is a reservoir of biodiversity, Merck made an initial investment of $1 million to INBio. In exchange, INBio will collect samples of plants and animals to be examined for new chemicals to be used as pharmaceutical drugs. If this 'biochemical prospecting' leads to marketable products then there are arrangements for sharing the royalties. The potential revenues through such type of agreement are enormous. Therefore, it is not surprising that the INBio experience is being closely followed by many tropical countries. INBio is showing that a well-managed biodiversity survey can result in tangible social and economic benefits.

Taxonomic expertise

Biodiversity surveys generate enormous numbers of specimens to be processed and identified. A large percentage of these specimens corresponds to species unknown to science that can only be described by a professional taxonomist with experience in the relevant group. For example, the entomological expedition of the Natural History Museum (London) to Sulawesi in 1985 collected 1690 species of Hemiptera of which 62% were new to science[2]. Closer to home, the Museo Nacional de Ciencias Naturales (Madrid) coordinates a comprehensive survey of the fauna of the Iberian Peninsula. As part of this project, a recent oceanographic collecting trip along the Southern coast of Spain yielded 25 000 specimens, mostly invertebrates. They comprised about 800 species; of them, at least 96 were new to science (M.A. Ramos, pers. commun.).

The existence of large numbers of rare and undescribed species is a major problem in comprehensive national surveys. INBio experience supports this contention. INBio's 'army' of parataxonomists does an excellent job in surveying both spatially and temporally different regions of Costa Rica. Huge collections are assembled and preliminarily sorted by technical staff in INBio headquarters. The common species are not a problem, but the process slows down with the rare or undescribed species.

Since it is impossible for INBio, or for any other single institution, to train local experts in every group, it must rely on a worldwide network of external experts. These experts do the work mostly on a voluntary basis and consequently their assistance to INBio is subordinated to other professional demands. To avoid these shortcomings, and to provide an effective and comprehensive taxonomic assistance international collaboration is required. For example, the natural history museums of London and Madrid are spearheading an initiative, hopefully funded by the EC, that would assemble a group of European institutions, and of expert taxonomists, to provide INBio with assistance in the identification of material as well as training of specialized personnel. The experience could then be extended to other countries such as Indonesia and Kenya that are beginning to develop biodiversity institutes. The purpose of this international collaboration benefits all parties involved. Tropical countries gain access to taxonomic expertise and to reference collections. European institutions have the opportunity to recycle a workforce of taxonomists that often are underemployed.

In this global problem, we suffer from a lack of global planning. For example, as emphasized by Gaston and May[6], the distribution of taxonomists is ill-matched to the species richness of taxa and to the jobs remaining to be done for different groups (e.g. too many vertebrate taxonomists, not enough fungi specialists). To palliate this problem we must resort to international collaboration. Worldwide databases of taxonomists need to be compiled. An example along these lines is DIRTAX, a computerized database of all taxonomists in Spain, which contains addresses, taxonomic and geographic areas of expertise, etc.[7]. Similar databases for other countries probably exist; if not, they should be compiled. The objective is to have access to a worldwide database of taxonomic expertise. This would allow us to identify areas in which training is redundant and others in which it is needed. Optimally, experts should be 'on-call' for identification of new material sent to them from the various national surveys. Here again we need to operate at a global scale. Planning, and setting priorities, must be clearly established to ensure efficiency and avoid undue duplication of effort.

Finally, even if we had a worldwide 'corps' of experts to determine new taxa, we also need appropriate information technology which would allow routine identification of material by nonexperts. This again would facilite a more efficient use of personnel and resources. The technology is available. I am most familiar with the effort of the Dutch foundation ETI (Expert-Center for Taxonomic Identification) who are developing, in CD-ROM format, user-friendly software that allows one to identify taxa using an approach that includes an abundance of diagrams, drawings, photographs and even moving images[8]. Such interactive systems will become an indispensable tool in biodiversity inventories.

Conclusions

Taxonomy, in spite of its devotion to orderliness and nomenclatural zeal, has done a poor job at coordination and planning. Driven by individual initiatives and personal preferences we find ourselves in a position in which we do not even know how many species have been described (estimates range from 1.4 to 1.8 million) – even less an adequate assessment of the task that lies head. We need more computerized databases amenable to constant updating instead of, say, lavishly published taxonomic monographs.

Recent years have witnessed a renewed recognition for taxonomy and its practitioners. But the same spotlight forces us to review the standard working methodology: it is too slow and does not readily respond to the needs of outside users, such as applied scientists, policymakers or, even, private companies. The solution must include international collaboration, use of tools from modern information technology and, most importantly, the establishment of priorities. Efforts to increase the degree of coordination in biodiversity studies are underway in several countries. The United States, in response to this need, is in the process of creating a 'Biological Survey', an ambitious institution that will fund and coordinate biodiversity studies (e.g. Ref. 9). At a more modest level, but adequately funded, the Spanish national science funding agencies decided, over five years ago, to channel all support for research on taxonomy and faunal surveys through three national-level projects: Flora Ibérica, Fauna Ibérica and Flora Micológica. As the names suggest, the goal is to compile a complete biodiversity survey of the Iberian Peninsula. Such financing structure allows for some degree of coordination. For example, at this time the project Fauna Ibérica, managed by the Museo Nacional de Ciencias Naturales, funds and coordinates the activities of over 80 taxonomists (working in universities, research centers or as private specialists) all over the country.

At the international level, museums and allied institutions must organize into networks to implement a change in working methods. This is necessary both in terms of developing more-efficient approaches to a global challenge as well as in devising a strategy to lobby international funding agencies. Obviously, a respectable amount of money is needed to carry out the proposed inventory and analysis of biodiversity. However, the level of funding needed to map out the biodiversity of this planet is not superior to that already allocated to study the human genome or in the construction of ever more powerful particle accelerators, not to speak of space exploration. I mention these examples to emphasize that the financial request is not utopian and the knowledge of our natural surroundings is as important as deciphering the organization of our genome or the structure of the atom. If taxonomists, and the institutions that house them, have not been able to muster support, it is because they lack the image of progress and modernity that physicists and molecular biologists have so successfully conveyed. To change the image we must propose new approaches, and most importantly, set deadlines. But, even if we had the money, we need to deliver. Large natural history museums are often too engrossed into their own distinguished past and traditions. If they continue in this frame of mind, unable to rise to the new challenges, they will indeed turn into museums of themselves.

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How Much do we Know About the Current Extinction Rate?

Fraser D.M. Smith, Robert M. May, Robin Pellew, Timothy H. Johnson and Kerry R. Walter

Since about 1600, 486 animal species have been recorded extinct. This represents about 0.04% of all animal species so far described. In the same period, 600 plant species are known to have disappeared, about 0.25% of the total. These figures are much smaller than those of the Permian/Triassic and Cretaceous/Tertiary mass extinctions. One might therefore conclude that at present life on earth is at comparatively little risk of extinction. However, there is a growing body of data to show that the converse is true.

Diamond[1] argues that the threat of mass extinction is considerable. For some regions of the world there are huge differences between the number of species known to be extinct and the number of species possibly extinct. Any taxonomic group or geographical region which is poorly studied will appear to be in good health by the former criterion, but if it is competing for space and resources with humans it may be in a poor state by the latter criterion. In the species-rich and heavily deforested Malay Peninsula only 122 out of 266 previously described species of freshwater fish were found over a four-year period[2]. King[3] lists one extinct bird species from the Solomon Islands, whereas Diamond[1] reports that 12 species have no definite records since 1953, and according to the islanders, some of these have been exterminated by cats.

Fraser Smith and Robert May are at the Dept of Zoology, University of Oxford, South Parks Road, Oxford, UK OX1 3PS; Robin Pellew, Timothy Johnson and Kerry Walter are at the World Conservation Monitoring Centre, 219 Huntingdon Road, Cambridge, UK CB3 0DL.

Conservationists assert that we are entering a mass extinction of similar magnitude to those at the end of the Permian and Cretaceous, where on each occasion about 50% of all recorded fossil species died out[4]. Because tropical rainforests are thought to contain up to 30 million species (see Refs 5,6), and are being logged, conservationists argue that we are losing many thousands of species each year. Critics of this argument[7] reply that species which have not yet been described exist only in the realm of speculation, and therefore, as far as the conservation of biodiversity is concerned, there is nothing for humans to worry about. The evidence presented here suggests that of the two arguments, the conservationist one is nearer the mark, but for the wrong reason.

Regions of the world and taxonomic groups that have been well studied show a relatively high proportion of extinctions, while those receiving little attention show relatively few. One would thus expect that by investigating some of these geographical and taxonomic backwaters, many species described decades ago, but unstudied since, would not be found, and therefore considered extinct. The difference between this argument and the traditional conservationist one is that this argument does not rely on the existence of 'phantom' species.

Extinction trends

The figures on extinction presented here are more likely to be underestimates than overestimates, though more accurate estimates would require research on a gigantic scale. While many regions of the world have good faunal and floral records, few of these fauna and flora have yet been subjected to extinction assessments. A human-caused mass extinction is probably not yet with us, but there is plenty of evidence that human activities are the main contributing factor to the significant rise in extinction rates over the past 400 years (see Ref. 2). This rise is shown in Fig. 1a, which documents the trend in animal extinctions (historical data on plant extinctions are very limited). Two reasons for the sharp increase between 1850 and 1950 are (1) that before 1850, for groups such as molluscs, information on extinctions was simply not available (Fig. 1b) and (2) the extinction record for all groups before 1850 is very patchy. However, as Fig. 1c shows, even well-documented groups, such as